A TECHNICAL ASSESSMENT OF THE WASTE DISPOSAL CONCEPT IN "PROGRESS REPORT NO. 1 - CONCEPTUAL DESIGN STUDY - SAN FRANCISCO RESOURCE CONVERSION CENTER"

PREPARED FOR

THE CITY AND COUNTY OF SAN FRANCISCO

AUGUST, 1979

A TECHNICAL ASSESSMENT OF THE WASTE DISPOSAL CONCEPT IN

"Progress Report No. 1 - Conceptual Design Study - San Francisco Resource Conversion Center"

August 1979

CSI RESOURCE SYSTEMS, INC.

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SECTION I

INTRODUCTION AND APPROACH

The City and County of San Francisco is facing a serious solid waste disposal problem. The City's contract for disposing of its solid waste in Mountain View expires in 1983. Consequently, the City must act expeditiously to develop a replacement for the current land disposal system. The new system could include a resource recovery plant and a landfill for disposal of residues and ash, or could simply include one or more new landfills for the disposal of unprocessed solid waste. In either case, source separation and other recycling programs could reduce the amount of material for land disposal.

In September 1978, the City received "Progress Report No. 1; Conceptual Design Study: San Francisco Resource Conversion Center." The report was submitted to the City by Sanitary Fill Company, a joint venture of Sunset Scavengers and Golden Gate Disposal Company. The report presents the results of several years of cooperative effort among Sanitary Fill Company, the City, and Pacific Gas & Electric to develop an environmentally superior alternative to the landfilling of the City's solid waste, and to avert a waste disposal crisis in the mid-1980's.

Sanitary Fill Company proposed a 1900 ton per day resource recovery facility for processing the solid waste currently being handled at the transfer station in Brisbane. The proposed facility would separate metals and other heavy materials from the waste, and use the recovered combustible fraction as fuel in a steam power plant to generate electricity. The system would substantially reduce the amount of material for landfilling while recovering otherwise wasted energy and metals.

In February 1979, Roger Boas, the City's Chief Administrative Officer, retained CSI Resource Systems, Inc. (Resource Systems) to review the Sanitary Fill Company report.* The purpose of the

*Resource Systems was assisted in this effort by its land disposal subcontractor, SCS Engineers; and by Smith Barney, Harris Upham & Co., Inc., who provided advice on project financing issues.

Resource Systems' effort was to perform an independent review and evaluation and to make recommendations to the City on how to proceed. The technical evaluation included assessing the performance of the proposed solid waste disposal system and estimating overall project economics. The evaluation also included identifying and comparing several potentially feasible alternatives with the Sanitary Fill Company proposal. Resource Systems focused on four key questions:

- *What is the likely performance of a resource recovery system of the Sanitary Fill Company design?*
- *What are the costs and overall economics of the Sanitary Fill Company project, and how do these economics compare to reasonable resource recovery and land disposal alternatives?*
- *How long will it take to implement the project proposed by Sanitary Fill Company?*
- *How should the City proceed to implement a resource recovery project which serves and protects the needs and interests of the ratepayers?*

Approach

A resource recovery facility has two functions...to dispose of solid waste, and to produce energy and materials for sale in the marketplace. Thus, a resource recovery project serves the public purposes of waste disposal and energy and materials conservation, and the business purpose of production and sale of valuable products. Consequently, the process of implementing a resource recovery project must be sensitive to the needs of the public for reliable, economic, and environmentally sound disposal of solid waste, and to the demands on the private partner to run a profitable manufacturing business.

A successful resource recovery project has seven key ingredients:

- An *energy buyer* who is willing and able to enter into a long-term agreement to purchase energy.

- A reliable *supply of solid waste*...the feedstock to a resource recovery plant.

- A *technology* which can safely, efficiently, and reliably convert the waste into a saleable form of energy in the quantities and of the quality required by the buyer.

- *Revenue streams* which are sufficient to cover operating and maintenance costs, debt service, and operator profits.

- Overall *project economics* which are competitive with alternative means of waste disposal.

- Public and private *partners* who are willing and able to assume responsibilities for the project risks which are in their respective domains, and for performance of their respective functions in the project (e.g., assurance of waste supply and payment of disposal fees, assurance of facility performance and cost, and assurance of energy purchase).

- *Procurement, financing, and project implementation approaches* which meet the requirements of existing laws and regulations, and which are consistent with the risk postures and risk management capabilities of the partners in the project.

The charge to Resource Systems in evaluating the Sanitary Fill Company proposal was to determine if the key ingredients to a successful project exist, and if the needs and interests of the public and private partners in the project can be well-served by the proposed implementation scheme. Accordingly, Resource Systems' efforts included:

- Review of feasibility study work conducted over the last several years by Sanitary Fill Company.

- Review of design documents and data.*

*At the time of Resource Systems' review of the Sanitary Fill Company proposal, the preliminary designs for the recovery facility were not available. Consequently, the findings reported in this report are based on the conceptual design presented in their progress report, discussions with Sanitary Fill Company personnel and subcontractors, engineering judgements, and data from the testing of developmental and operating resource recovery systems.

- Review of waste quantity and composition data.
- Evaluation of markets for energy and recovered metals.
- Assessment of landfill site availability and land disposal costs.
- Identification of alternative resource recovery systems and development of their performance characteristics, including preliminary mass and energy balances.
- Review of alternative methods for the codisposal of solid waste and sewage sludge.
- Evaluation of the economics of the alternative resource recovery systems, including comparison of estimated capital cost, O&M costs, and debt service.
- Evaluation of the environmental characteristics of the alternative resource recovery systems.
- Estimation of the time required to implement each of the alternative resource recovery systems.
- Review of project financing alternatives and requirements.
- Review of the key legal authorities and requirements for project implementation.
- Identification of major project risks and definition of alternative methods for allocating and/or sharing the risks.

Resource Systems' approach to this assignment followed five key steps, the results from which are in each of the remaining sections of this report.*

STEP ONE:	WASTE QUANTITY AND QUALITY...
(Section II)	How much solid waste is generated by the City? What is its composition? Is there a pending problem which warrants serious investigation of disposal alternatives?

*Resource Systems' conclusions and recommendations are summarized in: *A Feasibility Review of the Waste Disposal Concept in "Progress Report No. 1 - Conceptual Design Study - San Francisco Resource Conversion Center";* August, 1979.

STEP TWO: MARKETS FOR RECOVERED PRODUCTS...

(Section III) Do markets exist for energy and materials potentially producible from solid waste? What form of product is required, and at what quantity? Are the markets substantial enough to justify consideration of resource recovery as a disposal alternative?

STEP THREE: WASTE DISPOSAL ALTERNATIVES...

(Section IV) Do sites exist for the continuing long-term land disposal of the City's solid waste? If markets exist for the products of resource recovery, what are the technological alternatives (in addition to the concept proposed by Sanitary Fill Company) which might best serve the needs of the markets, and what are their performance characteristics?

STEP FOUR: ECONOMICS OF THE ALTERNATIVES...

(Section V) When might each of the disposal alternatives be available for use? What will be the net disposal cost for each of the alternatives? Which alternatives are economically competitive?

STEP FIVE: TECHNICAL RISKS...

(Section VI) What key uncertainties affect the selection of a waste disposal alternative and/or the form and substance of an agreement with private industry to provide for disposal of the City's wastes?

Alternatives Evaluated

The 1900 TPD (tons per day) facility proposed by Sanitary Fill Company will include front-end processing (shredding, screening, and air classification) of the incoming solid waste to produce a fuel product, magnetic metals, a mix of non-magnetic metals, and residue for disposal. The fuel will be fired in boilers to produce steam. The steam will be used to produce electricity for sale to Pacific Gas & Electric or the California Department of Water Resources. The recovered metals will be sold to secondary materials reprocessors. By-passed waste and system residues will be landfilled. Figure 1 illustrates the Sanitary Fill Company System.

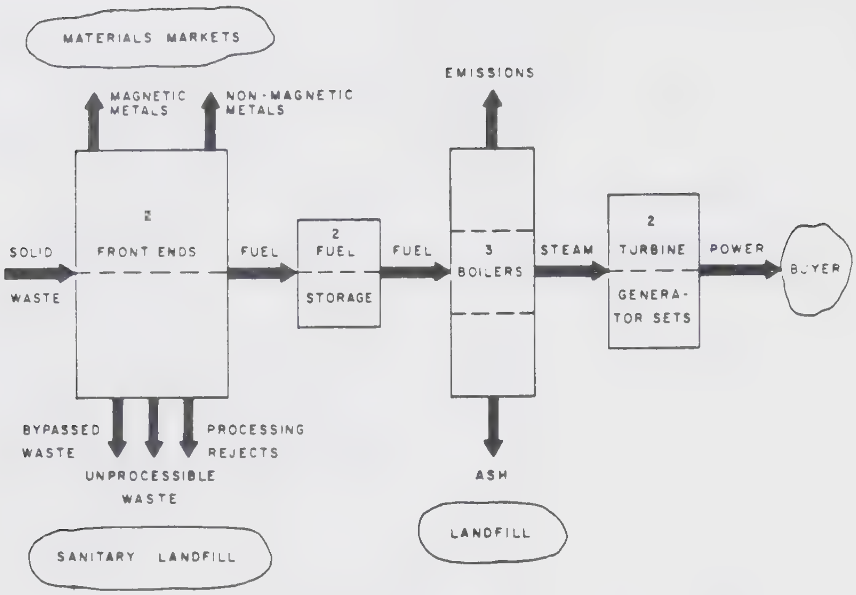

Figure 1. Sanitary Fill Company System.

For the purpose of comparison, Resource Systems chose four alternatives to the Sanitary Fill Company design. The alternatives included:

- Landfilling of the solid waste, either in existing landfills or at a new site acquired by the City.

- The Sanitary Fill Company design without the second steam turbine generator. Figure 1, without the second steam turbine generator, illustrates this alternative system.

- Fuel preparation at a Brisbane plant, with rail transport of the fuel to remote boilers which produce steam for sale to industry. This alternative is referred to as the "Split System"; the boiler facility is assumed to be located in the Pittsburg/ Antioch area. This alternative employs the same technology as has been proposed by Sanitary Fill Company. However, location of the boilers outside of the Bay Area could make it considerably easier to obtain the air permits necessary for construction and operation of the facility. Figure 2 illustrates the Split System.

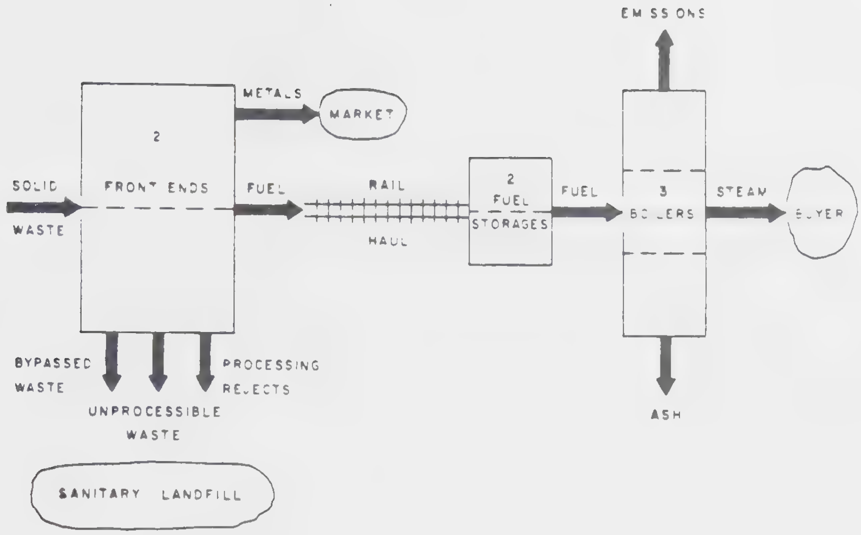

Figure 2. Split System.

- Massburning of unprocessed waste at Brisbane to produce steam and electricity. This alternative includes no front-end processing of the incoming waste, and is considered the most proven energy recovery technology available. However, massburning systems produce considerable amounts of ash, much of which is the metals and glass contained in the incoming waste. Figure 3 illustrates the Massburning Waterwall System.

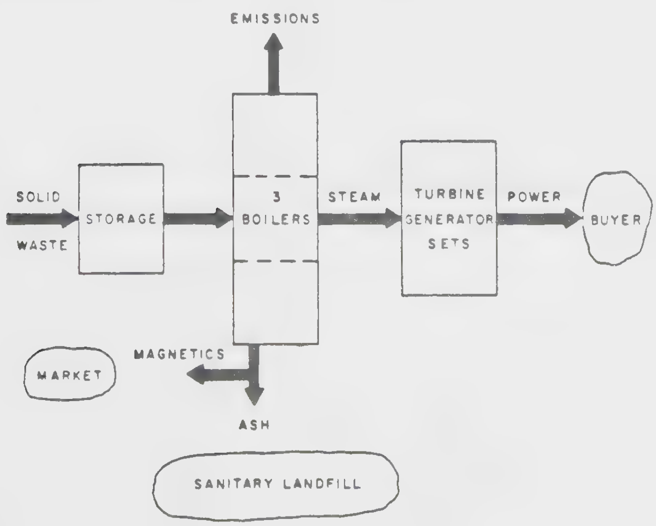

Figure 3. Massburning Waterwall System.

SECTION II

SAN FRANCISCO SOLID WASTE

Solid wastes generated in the City and County of San Francisco include municipal (or residential), commercial, and industrial wastes, demolition waste, and sewage sludge. Municipal solid waste (MSW) is collected by franchised collectors, each of whom holds exclusive service area contracts. Commercial, industrial, and demolition wastes are collected and disposed of on a private contract basis. Sewage sludge produced by the City's wastewater treatment plant is collected and landfilled under individual contracts.

Pursuant to the 1932 Initiative Ordinance, the Board of Supervisors of the City must designate a disposal site for all wastes collected by franchised collectors. However, disposal of the commercial and industrial solid waste generated in the City is also of concern to the City's solid waste management planners.

Municipal Solid Waste

The municipal waste generated within the City is collected by Sunset Scavengers and Golden Gate Disposal Company, taken to a transfer station in Brisbane, and then to the Mountain View sanitary landfill for disposal. A review of transfer station records for municipal and commercial tipping covering the last three years, indicates receipts of approximately 500,000 tons of solid waste per year. This amount corresponds well to the estimate presented by Sanitary Fill Company of 492,750 tons per year.

The amount of waste being managed at the transfer station rose 5 percent in 1976, 6 percent in 1977, but only 1 percent last year. Because the population of the City and County has been declining, the growth in waste generation could be caused by increased economic activity (e.g., tourist and convention business), increases in per capita waste generation rates, or increases in the amount of commercial and industrial waste arriving at the transfer station.

Sanitary Fill Company has conservatively assumed that the amount

of waste available today is what will be available in the future. Such conservatism is consistent with recent projections. Current estimates (Franklin Associates, 1979) suggest a nationwide average increase in solid waste generation of 30 percent in the 13-year span between 1977 and 1990. The U.S. Census Bureau is projecting only a 9 percent growth in population during the same 13 years. Thus, the annual *per capita* generation rate might be expected to increase by 1½ percent per year. In San Francisco, this limited growth in the per capita waste generation rate will likely be offset by the anticipated slight decline in population. Furthermore, there are nationwide trends towards increased source segregation, materials recycling, and reduction of the amount of glass being disposed of by households through legislated use of returnable glass containers. The effect of each of these actions is to reduce the total amount of material arriving at waste disposal facilities.

Composition--Sanitary Fill Company has reported the results of a single waste characterization test in which a sample of waste at the Brisbane transfer station was manually separated into its components. The sample was found to contain, on a wet basis, approximately 80 percent combustibles, 7 percent magnetic metals, 1.5 percent non-magnetic metals, and 11 percent glass, stones, and ceramics.*

The Sanitary Fill Company assessment of the waste composition differs somewhat from three composition studies performed in 1978 at the Brisbane transfer station by SCS Engineers for the California Solid Waste Management Board. In the SCS study, 60 samples were sorted for each season. Table 1 summarizes the SCS findings. The differences between the Sanitary Fill Company and SCS estimates may be significant. However, for planning and evaluation purposes, Resource Systems has assumed that the Sanitary Fill Company composition estimates, with minor variations, are adequate.

* Single point composition analyses can lead to large errors, because it is impossible to tell if the values are typical. To have confidence in measures of waste composition, it is necessary to take several samples at a time, and to sample during several time periods.

Table 1.

San Francisco Solid Waste Composition

	Estimated Solid Waste Composition (% by weight)*		
	Summer 1977	Fall 1977	Winter 1978
Organics†	76.2	61.6	64.4
Ferrous	2.9	4.9	4.4
Aluminum	0.5	1.3	0.9
Glass	4.9	7.6	5.4
Corrugated	7.8	10.9	8.1
Newsprint	5.7	9.7	7.1
Plastic	2.1	4.3	9.1
Garden	---	---	0.3

*Stratified sample with 60 300-lb samples per sampling period; confidence limits @ 90 percent.

†Includes all materials not included in other categories.

ref: SCS Engineers; Survey of Solid Waste Quantity & Composition in the San Francisco Bay Area; for: California State Solid Waste Management Board; Sept. 5, 1978; p. 46.

Sewage Sludge

The sewage treatment plants of the City are undergoing major expansion and upgrading. By the time a new solid waste disposal facility can be available, all sanitary and storm water flows will be collected and biologically treated in one of two plants. These plants are expected to produce 250 to 500 tons per day of sludge which has been dewatered to approximately 20 to 40 percent solids. Thus, the dry weight of the sludge will be about 100 tons per day.

Typically the solid fraction of sewage sludge is less than 50 percent non-combustibles. After heavy rainfalls, when street dirt is washed into the storm sewers, the sludge may contain considerably more inerts, such as sand and grit.

Conclusions

San Francisco annually generates approximately 500,000 tons of municipal and commercial solid waste. In addition, the City will be generating over 30,000 tons (dry weight) per year of sewage sludge when its new wastewater collection and treatment system is operational. With its Mountain View disposal contract expiring in 1983, the City must seek an alternative solid waste disposal facility. The quantity and quality of the solid waste are such that resource recovery could be economically competitive with sanitary landfilling, if a high-quality market exists for the purchase of energy recovered from the solid waste.

SECTION III

MARKETS FOR RECOVERED PRODUCTS

Markets for the sale of energy recovered from solid waste generally fall into four categories: (1) electric utilities, for steam and/or electricity; (2) industry, for steam and/or electricity; (3) municipalities, for district heating steam; and (4) utilities and certain industries for solid fuel to supplement coal in existing boilers. Because of the unique fuel mix in the Bay Area, the last market need not be investigated. Markets generally exist for recovered magnetic and non-magnetic metals. Although markets for paper, and cardboard recovered from mixed municipal waste, may exist, it is generally more desirable to remove these materials through source separation and recycling programs.

Energy Markets

Electricity--At the present time, both Pacific Gas and Electric (PG&E) and the California Department of Water Resources have expressed interest in purchasing all the electric power generated by a San Francisco resource recovery project.

PG&E has estimated that it is willing to pay approximately 2.5¢ per kwh. Resource Systems' review of the PG&E cost of generation, coupled with experience around the United States in the relationship between cost of generation and the purchase price for waste-derived electricity, indicates that the preliminary estimate of 2.5¢ per kwh is not unreasonable.

The California Department of Water Resources would purchase power to operate pumped-storage hydroelectric facilities. The Department might offer more operating flexibility because it accepts power on a dump basis (e.g., whenever it is generated). Recent Department power purchase contracts consistently show a purchase price for electricity lower than the PG&E preliminary figure. However, since the Department considers the generator's marginal cost of producing power in its pricing formulas, a more favorable price may be possible.

Steam--There are few large industrial steam customers in the immediate San Francisco area. Within the City, PG&E operates a downtown steam loop which, unfortunately, can take less than half the *average* production of a San Francisco resource recovery facility. As a result, the PG&E steam loop is not a viable market.

Several large industrial plants located in the Pittsburg and Antioch areas have the potential of accepting all the steam from a 1900 TPD resource recovery project. Initial discussions indicate that these markets may be attractive. However, other municipalities in the Bay Area are developing waste-to-energy projects which focus on these industrial steam customers. Since none of the potential markets are located within the City and County of San Francisco, the political difficulties of developing the markets could be formidable.

Materials Markets

Magnetics--At the present time, recovered magnetic scrap finds a strong international export market on the West Coast. Although there are several local steel fabricators, there are very few grey iron or primary steel foundries. Consequently, Bay Area recovered magnetics must be shipped elsewhere for reuse.

Magnetic materials recovered prior to incineration can be sold at approximately $35 per ton F.O.B. point-of-sale. The West Coast market appears to have a price stability which is not characteristic of the highly volatile Midwestern and East Coast magnetics markets. Thus, the current price may represent a long-term planning price.

Local markets for magnetics recovered from incinerator residue are more problematic. Because of oxidation of the metal, loss of coatings such as tin, and trace metal contamination, it is unlikely that incinerated magnetic metals could be sold for more than half the price received for front-end separated metals.

Non-Magnetic Metals--There are two basic types of markets available for non-magnetic metals...primary can recyclers, and mixed scrap dealers. Reynolds Aluminum has indicated a strong interest in buying the recovered can stock for eventual use in the new recycled aluminum mills they are planning for the southeastern portion of the

United States. For can stock which meets a rigid specification, Reynolds and other primary aluminum smelters are offering around \$400 per ton F.O.B. the buyer. Quotes from San Francisco secondary materials buyers are slightly below this level.

Mixed non-magnetic metals concentrates can be sold to companies that recover non-magnetic metals from wrecked automobiles, and to other scrap dealers. Middlemen with dense media beneficiation processes in the Oakland/Alameda area have expressed some interest in purchasing a mixed non-magnetic metal concentrate which is at least 50 percent (by weight) non-magnetic metal. The concentrate can probably be sold for \$240 per ton of metal content F.O.B. the buyer.

Conclusions

Markets exist for the sale of energy recovered from solid waste. The most promising market appears to be for electricity for sale to Pacific Gas & Electric or to the California Department of Water Resources. However, markets for steam may exist in the Pittsburg and Antioch areas. Markets also exist for recovered magnetic and non-magnetic metals. It is, therefore, appropriate to seriously investigate resource recovery as an alternative to the land disposal of solid waste.

SECTION IV

SOLID WASTE DISPOSAL ALTERNATIVES

Sanitary Fill Company, in conjunction with the City and Pacific Gas and Electric, has worked for several years to develop an alternative to land disposal in Mountain View by 1983 (when the City's disposal contract expires). The purpose of the Resource Systems' study was not to redo the previous work, but rather to investigate certain alternatives to the Sanitary Fill Company proposal which had been rejected, but which deserved comparison to the current proposal. Consequently, in addition to an in-depth review of Sanitary Fill Company's conceptual design for a refuse-derived fuel (RDF)-based steam/electricity recovery system at the Brisbane transfer station, Resource Systems has evaluated*:

- Sanitary landfilling at existing or new sites.
- RDF production at Brisbane, with shipment to the Pittsburg or Antioch area for firing in a dedicated boiler to produce process steam for one of the identified industrial users.
- Application of massburning waterwall combustion technology at Brisbane to generate steam for electricity production.

Sanitary Landfilling Alternative

The City's municipal solid waste is currently disposed of in a sanitary landfill in Mountain View. However, the transfer operation at Brisbane is an important element in the disposal system. Collected waste is dumped from the collection vehicles into a shallow pit at the Brisbane transfer station. The waste is then pushed with a bulldozer to one end of the pit floor, where it falls through an opening into open top trailers parked underneath. When full, the trailers are

*Resource Systems also reviewed several alternatives for the codisposal of solid waste and sewage sludge. A summary of the review is presented in Appendix A. The upcoming seriousness of the sludge disposal problem warrants further investigation of codisposal, especially indirect drying and cocombustion of the sludge with solid waste in a solid waste incinerator.

truck-hauled to the Mountain View landfill. After arriving at the landfill, the trailers are dumped and the solid waste is landfilled.

In the landfill operation, solid waste is spread and compacted with heavy earth-moving equipment. At the close of a working day, the compacted waste is covered with a thin layer of soil. When entire sections of the fill are completed, the surface is capped with more soil, graded to erosion resistant contours, and planted with grasses and trees. In addition to leachate control and ground-water monitoring, methane gas produced during the biological stabilization of the solid waste is collected, separated from comingled diluting gases, and sold.

The landfill at Mountain View is nearing capacity. The current contract between San Francisco and Mountain View expires in 1983. However, preliminary discussions indicate that a short one-year extension of the disposal contract could probably be negotiated.

Alternatives to landfill disposal at Mountain View after 1983 include disposal at another existing sanitary landfill or at a new site developed by the City.

Existing Sites--Alternative existing landfill sites possibly available for use after 1983 include the Ox Mountain site in San Mateo County, the Vasco Road and Altamont Hills sites in Alameda County, the Redwood Sanitary site in Marin County, and the Richmond Sanitary Service site in the City of Richmond.

Ox Mountain--The Ox Mountain site, owned and operated by Browning-Ferris Industries, consists of two major canyons. One canyon is permitted for municipal solid waste disposal and is currently receiving wastes. This canyon has an estimated capacity in excess of 8 million cubic yards and is projected to meet San Mateo County needs through 1985. The addition of San Francisco's waste beginning in 1984 (estimated to be 555,000 tons per year, or about 1.1 million cubic yards per year) would reduce the site life by one year. Thus, the existing canyon would be available for use by San Francisco for only about one year, or through 1984.

The second canyon has an estimated capacity of 26 million cubic yards. Canyons 1 and 2 together could meet San Mateo County waste disposal needs through the year 2000. The addition of San Francisco waste would reduce site life by about seven years. Thus, assuming both canyons are filled, San Francisco wastes could be accommodated at Ox Mountain for about 11 years (through 1994).

Vasco Road--The Vasco Road site, owned and operated by Ralph Properties, Inc. and Depaoli Equipment Company, encompasses an area of approximately 900 acres in Alameda County. About 320 acres are permitted for municipal solid waste disposal. The permitted portion of the site is estimated to have remaining capacity in excess of 15 million cubic yards. At the current use rate, the remaining life of the permitted area is in excess of 70 years (through the year 2050). The addition of San Francisco waste beginning in 1984 would significantly reduce the site life, leading to landfill completion by 1993. Expansion of the permitted area to encompass the entire 900 acres of the site would extend this life significantly.

Altamont Hills--The Altamont Hills site, owned and operated by the Oakland Scavenger Co., is located in Alameda County. The site consists of several canyons having an estimated combined capacity of 110 million cubic yards. The site is scheduled to open by mid-July 1979, and has an estimated life in excess of 60 years. The site is slated to accept wastes primarily from the City of Oakland. If San Francisco wastes were accepted beginning in 1984, the anticipated disposal life would be reduced by about 26 years. The site would be filled to capacity around the year 2017.

Redwood Sanitary--The Redwood Sanitary site encompasses 600 acres in Marin County. Approximately 420 acres have been prepared for solid waste disposal. The site is owned and operated by Edward and Jordan Smith. Only 150 acres are included in the operating permit, and approximately 20 percent of the permitted capacity remains. Assuming that permits can be obtained for waste disposal on the entire 600 acres, it is estimated that from 30 to 35 years of dis-

posal life remain, based on the current disposal rate of 120,000 tons per year.

The practicality of using this site is questionable. With San Francisco waste deliveries beginning in 1984, disposal life would be about four years (through 1988). If San Francisco disposed of its wastes at this site, transfer trucks would move through San Francisco's downtown area and over the Golden Gate Bridge.

New Sites--A survey of State Solid Waste Management Board data on suitable land formation, and a review of soils and hydro/geological survey data from the State soils survey, indicate that several suitable sites may exist for City landfill development. Site visits confirm that a number of apparently suitable sites are undeveloped. Review of local and regional development plans shows that sanitary landfilling would be a consistent land use. Four sites have ready access from major highways, suitable ground formation, and are undeveloped. Discussions with Agricultural Extension Agents indicate that the land is potentially available.

The four identified sites include one flatland and three canyon locations. Assuming that a site must receive San Francisco's waste for a minimum 20-year period, a hilly or canyon site will be approximately 420 acres, including 50 percent extra land to use as a buffer. A flatland site requires approximately 700 acres, including buffer.

Any new landfill site will have to be developed in conformance with State requirements and Federal Guidelines promulgated under the Resource Conservation and Recovery Act (RCRA) of 1976. The RCRA Guidelines have been published for comment and are generally in accord with current California regulations. RCRA Guidelines cover design and operation, leachate and gas migration controls, and routine monitoring.

Resource Recovery Alternatives

The alternative municipal solid waste-to-energy systems analyzed include: (1) refuse-derived fuel-based systems utilizing the Sanitary Fill Company concept, but including minor variations such as separating the fuel production and energy conversion portions of the system;

and (2) the direct utilization of unprocessed municipal solid waste in specially-designed boilers.

The Sanitary Fill Company processing scheme involves the mechanical upgrading of raw solid waste into a relatively uniform fuel for use in new, specially-designed boilers to raise steam for electric power generation. Physical separation of the fuel preparation from the steam generation elements of the system makes it possible to satisfy the needs of distant industrial steam markets.

Alternative One: Sanitary Fill Company System--The proposed Sanitary Fill Company system is depicted in Figure 4. Solid waste is received at the existing transfer station in Brisbane and processed in one of two parallel front-end systems. Each front-end system converts the solid waste into fuel while separating marketable magnetic metals and a mixed non-magnetic concentrate. Wastes which the process cannot handle, such as mattresses and refrigerators, are separated prior to processing and sent to the landfill. The front-end system also yields residues for disposal.

Solid refuse-derived fuel is produced 12 hours a day, 5 days a week, and placed into one of two parallel fuel storage systems, from which it is withdrawn for burning seven days a week. The fuel is fired in two of three installed spreader/stoker-equipped boilers. The steam generated by the boilers is passed to one of two turbine-generator sets to generate electric power. The products of combustion are cleaned of entrained ash in an electrostatic precipitator and vented to the atmosphere. Thus, the conceptual system is composed of a fuel preparation system and fuel conversion system.

Fuel Preparation System--Figure 5 is a simplified flow chart of the Sanitary Fill Company fuel preparation process. Municipal waste is received and unprocessibles, such as rugs and large metal objects, are manually separated. The remainder is pushed onto the feed conveyor to a large-opening trommel screen.

Material smaller than 12 inches in any two dimensions falls through the screen and bypasses initial size reduction. Pieces of board or pipe might also fall through the large holes (Woodruff,

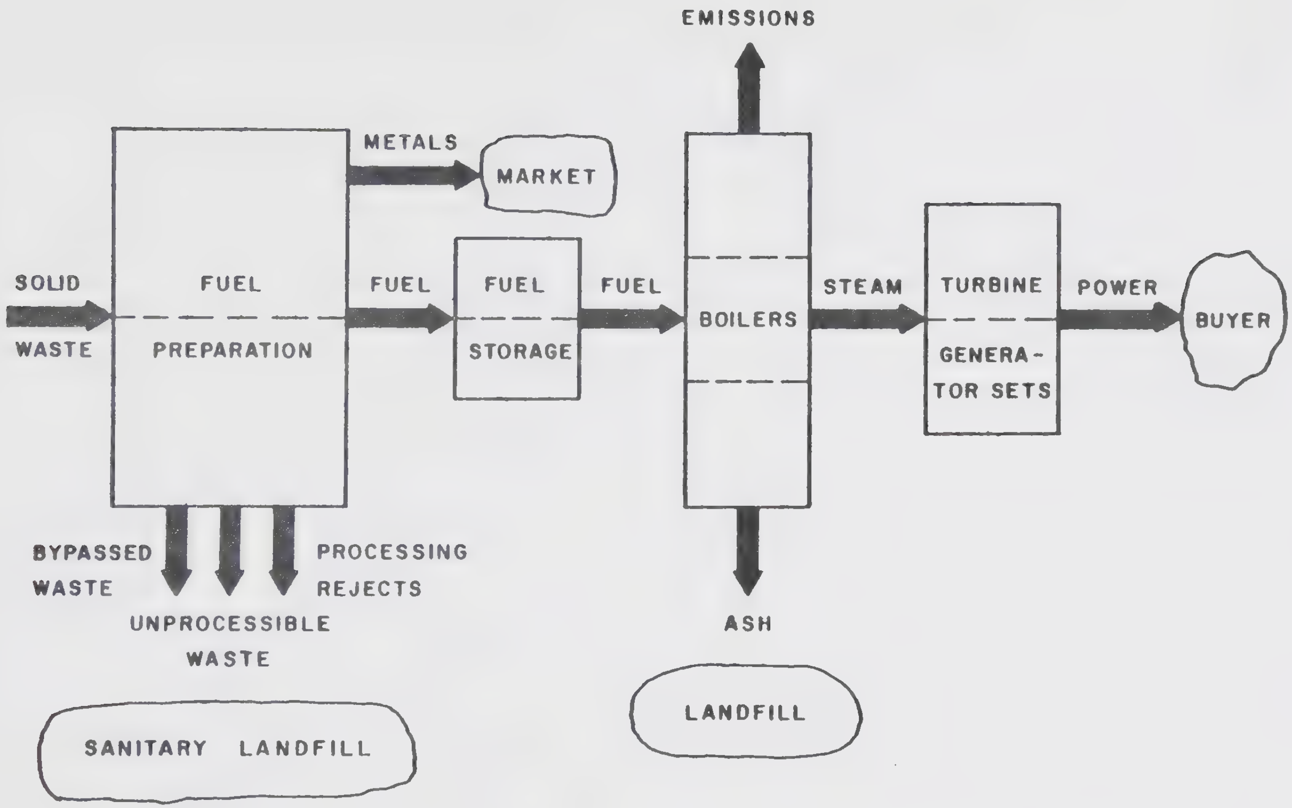

Figure 4. Sanitary Fill Company System

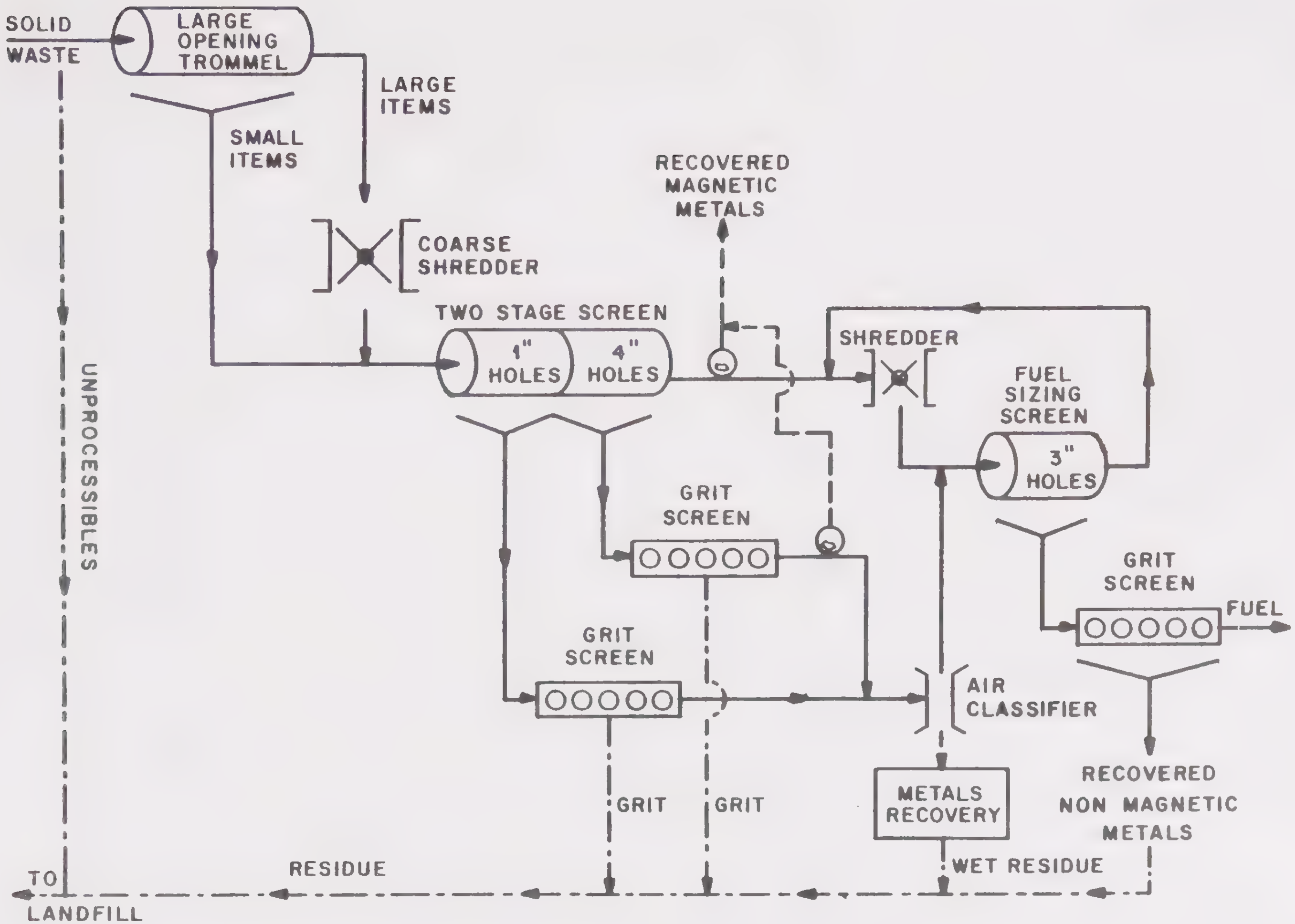

Figure 5. Sanitary Fill Company Fuel Preparation System

1978) and eventually reach the secondary shredder, where they could do considerable damage. Long boards and pipes might also "spear" through the trommel unless the first screen section is solid instead of perforated. Hence, the coarse trommel screen will serve to reduce the number of secondary mill outages, but will not eliminate them.

Large items (such as pallets, newspaper, and cardboard) are separated from small material in the large-opening screen and milled to simplify subsequent processing. Sanitary Fill Company proposes to use television cameras to inspect the feed to the shredder. Any objectionable materials, such as gasoline cans, are to be separated by an hydraulic tipper. Because of likely visibility problems and the relatively slow reaction time of hydraulic tippers, Resource Systems questions the practicality of this approach to minimizing shredder explosions.

The coarsely shredded waste and the underflow streams from the large-opening trommel are recombined and conveyed to a two-stage rotary screen. The first half of the rotary screen is equipped with relatively small holes, probably 1 to 2 inches in size, and the second half with 4-inch holes. Sanitary Fill Company expects essentially perfect separation of glass, cans and stones from the burnable waste by the rotary screen. The screen is modeled after the trommel installed by Waste Management in New Orleans. Experience there indicates that much of the glass, wet garbage, and yard waste in the stream will be separated by the screen, but a significant proportion of the aluminum cans and other metals will not be separated.*

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*Accurate analysis of screen performance is difficult because performance data are extremely limited. Resource Systems has assumed that the sparse New Orleans data base (Chrisom, 1978) is applicable. It can be assumed that all items which are small enough to fit through the small holes will be separated over the entire length of the screen. Items which cannot physically pass through the small holes, however, are effectively "seeing" a screen which is one-half as long as the New Orleans trommel. Based upon theoretical considerations and unpublished trommel experiments, it appears that separation efficiency scales logarithmically. Thus, performance of the trommel proposed by Sanitary Fill Company is expected to be only 60 to 70 percent of the published New Orleans performance for larger items, such as cans. As a result, Resource Systems estimates more metal and like contaminants in the fuel than does Sanitary Fill Company, which has assumed that halving the length of the screen will not affect performance.

Thus, complete separation of combustibles from non-combustibles may not occur.

Material passing through the 1-inch and 4-inch hole sections will be separately rescreened to separate fine material which is mostly non-combustible. Resource Systems believes that much of the fine organic material (such as coffee grounds and small pieces of paper), as well as dirt and chips of glass, will be separated from larger materials in the grit screen. As a result, the rescreened material will have upwards of 70 percent of the fines removed. This rescreening reduces fuel ash, but small pieces of fuel will also be lost.

The material falling through the 4-inch holes will also be passed under a magnet to recover magnetic metals. The material falling through the two-stage trommel and passing over the grit screens will be recombined and processed in a single air classifier, where all the materials which can be elutriated by a rising air column (the "light fraction") will be recovered and put into the fuel milling circuit. The air classifier is expected to recover paper, plastic films, and metal foils, along with cloth, cardboard, and any grit which was not removed on the grit screen.* Recent experience indicates that the air classifier may have to be adjusted so that aluminum is carried over with the light fraction, in order to prevent loss of heavy cardboard, plastic and wood, and thereby maximize fuel recovery. Hence, many of the aluminum cans separated in the second trommel stage may return to the fuel.

The material which drops in the air classifier is expected to be heavy objects, such as shoes, glass, ceramics, crushed cans, metal, garbage, and bones. It will be taken to a materials recovery step, where it is anticipated that rising current separators, or some form of dense media separation, will be employed to develop a 50-percent non-magnetic metals concentrate.

*Organics in with inerts are predominantly wet garbage through the first trommel section, and paper pieces through the second. Separate air classifiers for each underflow stream might result in lower ash fuel and/or better recovery rates because the classifiers can be tuned to accommodate the very different characteristics of each stream.

Returning to the two-stage trommel, the material which did not fall through the holes is larger than 4 inches. It will be passed under a magnet to recover more magnetic metals. The plus 4-inch material consists of paper, cardboard, wood, and occasional pieces of metal. It will be milled in a secondary shredder to make it small enough for use in the boilers.

The shredded waste stream will be combined with the air classifier "lights" and screened to separate fuel from oversize pieces. The material which is too large for the boilers will be recycled to the shredder for additional milling. Material which is small enough will fall through the screen and be processed over another grit screen. Sanitary Fill Company expects this screen to remove the last vestiges of dirt, glass and ceramics. This is supposed to yield a fuel with essentially no physically separable non-combustibles (Bartz, 1979).

Resource Systems expects that some of the glass and dirt not separated in the two-stage trommel will be embedded into the paper as it is milled, and cannot be separated in the grit screen. Aluminum cans and foil, which either fail to fall through the two-stage trommel or fly in the air classifier, will also be in the fuel. Hence, the fuel will likely contain at least some non-combustibles.

Energy Conversion System--The recovered fuel is taken to one of two parallel storage systems. Fuel is distributed in a uniform pile on a slab from a distributing conveyor. The surface of the pile is scraped off using a drag convoy onto a belt conveyor for transport to the boiler house, where it is metered through system surge bins into individual feed bins for each boiler.

The equipment to store, retrieve and meter refuse-derived fuels has been a constant source of operating problems in resource recovery plants. This poor performance may be due to inherent deficiencies in the concepts, to design and specification errors, or to overoptimistic estimation of material characteristics. However, the systems have worked well with other feedstocks, some of which are similar to municipal solid waste.

Steam Raising--The refuse-derived fuel (RDF) will be fired in two of three boilers equipped with spreader stokers. RDF-fired boilers have been operated successfully in Hamilton, Ontario, Canada, have been tested with 100-percent densified refuse-derived fuel (pelletized RDF) in Hagerstown, Maryland, and are being started-up in Akron, Ohio.

The refuse-derived fuel metered from the boiler's surge bin is blown into the furnace of the proposed units. Some of the smaller pieces of shredded waste (such as paper) burn in suspension. Larger pieces (such as corrugated board, sticks, and pieces of cloth or rubber) fall to a grate in the bottom of the furnace, where they burn. As the hot products of combustion (with their entrained ash) pass through the furnace, the gas gives up some of its heat to the water cooling the sides of the furnace and to the boiler tubes. The heat changes the water to steam, which then passes through some additional lengths of tubing within the furnace to increase the steam temperature and generate superheated steam.

Sanitary Fill Company proposes to maximize the system's thermal efficiency by using waste heat in the stack gases to preheat combustion air in an air preheater. However, heater air may increase NO_x formation (Hirayama, 1975). Since NO_x is a regulated air pollutant, use of air preheaters to improve boiler unit efficiency may cause undesirable emissions control problems.

The boilers will be equipped with "hot side" electrostatic precipitators designed to achieve in excess of 99-percent particulate removal. The hot side location, before the air preheater, treats dust entrained in flue gas with temperatures around 750 F. This type of equipment was selected to overcome problems associated with the high resistivity of well-burned RDF fly ash, which makes collection difficult. A hot side ESP is smaller per cubic foot of gas processed than precipitators operating around 450 F past the feedwater heater economizer. However, this benefit could be offset by higher construction and maintenance costs caused by the need for the design to accommodate thermal expansion of the equipment (Federal Register, 1979).

It should be noted that all ESP's on American waste-fired combustion units are operated at low temperatures. Hence, the hot side units will be a prototypical installation whose successful operation is expected, but is nonetheless uncertain.

Power Conversion--The superheated steam is piped to a turbine-generator, where it gives up some of its energy to generate electric power. The plant design provides for two 40 MW condensing turbine-generator sets. Power generation is maximized by using extracted steam in four regenerators. The low-pressure steam leaving the turbine is cooled in a condensor to convert it back to water for recycling to the boiler. The waste heat from condensing the steam is rejected to the atmosphere in a cooling tower.

The incremental investment for a redundant 40 MW turbine generator set with condensers, cooling towers, switch gear and installation might not be justified. The forced outage rate for such units is typically less than 1 percent of scheduled operating time. Scheduled maintenance involves a 2-to-3 week shutdown every three to five years. Furthermore, since even properly "moth-balled" turbines tend to degrade, there is doubt whether a standby turbine would operate when it is needed.

Alternative Two: Sanitary Fill Company System with Remote Boiler (Split System)--One alternative to the proposed Sanitary Fill Company system is referred to as the "Split System." Figure 6 is a schematic representation. The system is similar to the Sanitary Fill concept, with a few exceptions. The market for recovered energy is assumed to be an industrial steam user in the Pittsburg/Antioch areas. Consequently, the turbine-generator sets are eliminated. The fuel preparation system and the energy conversion system are physically separated, with fuel production at Brisbane and steam generation at the user's site. The two systems are connected through a rail transport system, whereby the fuel product is compacted into transfer containers, placed on railroad cars, and transported as a unit-train to the fuel user. At the user, full containers are offloaded and empty containers are put in their place for return to the fuel preparation

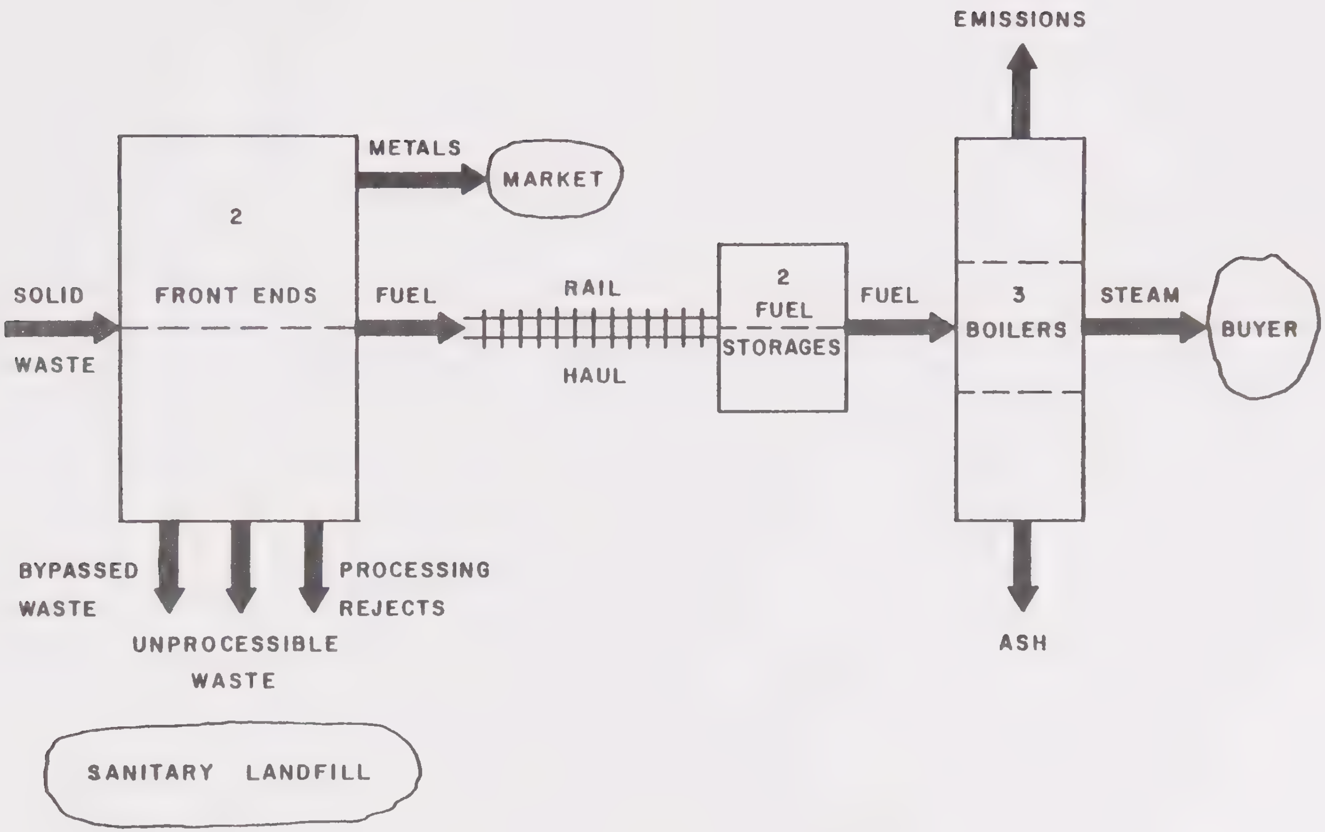

Figure 6. Split System

facility. As fuel is needed, it is ejected from the transportation containers and fed to the spreader/stoker-equipped boilers.

This approach has the advantage of generating lower temperature and pressure steam than that required for power production. Thus, the reliability of the units could increase significantly. However, a split system requires more people to operate, involves another actor in the project (the railroads), and increases the amount of handling of the fuel.

Alternative Three: Massburning Waterwall System--Massburning waterwall boilers were initially installed in Europe in the mid-1950's. The first American installation occurred in 1967. At the present time, there are over 200 massburning waterwall installations worldwide, and eight installations in the United States, including one which is generating steam of sufficient quality, temperature, and pressure for use in turbine-generators. The system is depicted as a block diagram in Figure 7.

Massburning waterwalls operate without front-end preparation. As-received waste is fed directly to a specially-designed grate in the furnace. To overcome imperfections in the fuel bed, massburning waterwalls use more air for combustion than do RDF-fired units. This increased air flow decreases the overall efficiency of converting the energy in the raw municipal solid waste to steam. It must be noted, however, that by not losing potential fuel in the front-end processing, the total amount of steam generated from a ton of municipal solid waste can be higher than that raised by a refined RDF/spreader-stoker system.

The massburning waterwall would be located on the Brisbane site, and would be equipped with a high efficiency electrostatic precipitator similar to the one employed in the Sanitary Fill Company concept. Such units have successfully met annual recertifications of performance to meet the stringent West German standards of 0.01 gr/SCF at 12 percent CO_2. The total particulate emission will be higher than in the refined RDF system, however, because more total fuel is being burned with more total air. Consequently, for the same pollutant concentration, the total emission will be greater.

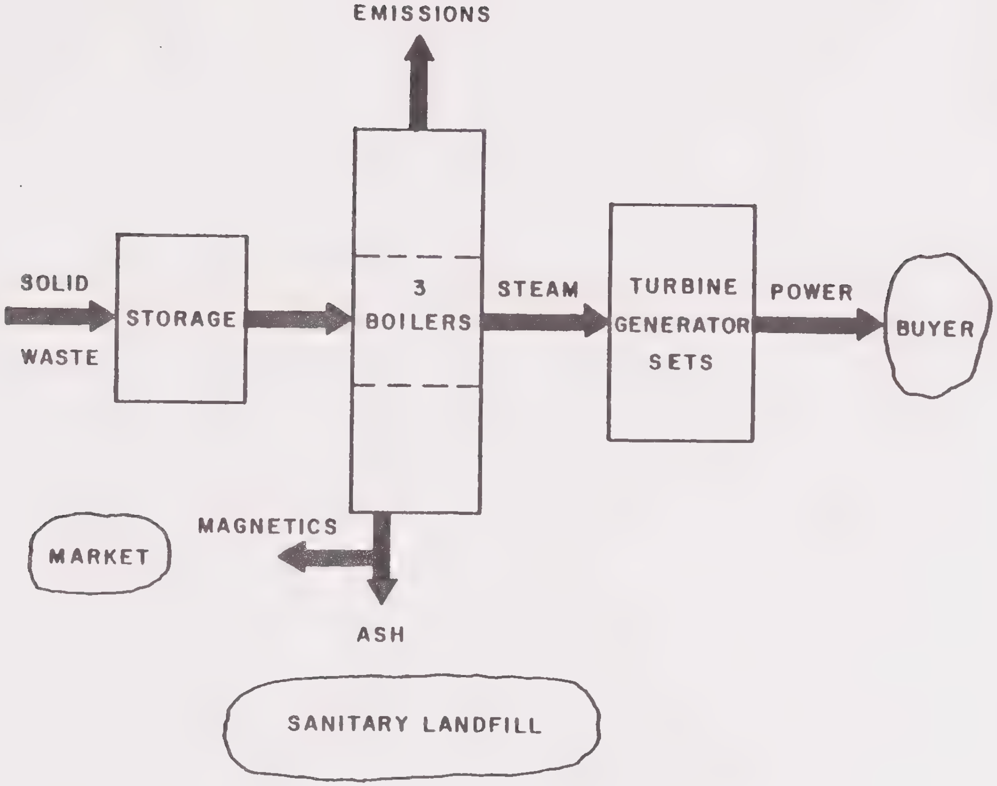

Figure 7. Massburning Waterwall System

Steam from the massburning waterwall boilers would drive a single turbine-generator set to produce electric power. This turbine-generator set would have a slightly lower conversion rate of steam-to-power than the refined RDF turbine-generator set because the unit would be operated with slightly lower pressure steam. As with the Sanitary Fill Company design, the turbine would have four stages of regeneration. The amount of ash leaving the furnace is substantially greater than that which leaves an RDF-fired system. The reason for this is that the entire waste is placed in the furnace and burned rather than only that material which is clearly combustible. However, magnetics and other materials can be recovered from the bottom ash leaving the furnace. The magnetics have a lower value than magnetics from front-end separation because they have been burned in the furnace, and many of the valuable coating metals have been removed. Other materials are also less valuable...their use is primarily for road paving filler.

The energy required to operate a massburning waterwall is lower than that required to operate the refined RDF system. Massburners have larger combustion air fans that require greater horsepower than spreader/stokers, but they eliminate the power needed to operate the fuel preparation system.

Performance of Resource Recovery Alternatives--The technical performance expectations for RDF and massburning waterwall-based systems are summarized in Table 2. The expected performance estimates are converted into annual outputs in Table 3.

The variations in expected performance between Resource Systems' analysis of the Sanitary Fill Company concept and that presented in their Progress Report stem principally from different process engineering assumptions and data bases. For example, Resource Systems believes that screens will separate both pieces of dirt and glass, and small pieces of combustible materials. Further, some dirt which has been rubbed on the surface of paper will remain with the paper and not be separated by screens. Thus, as a result of different opinions of the flow of materials in the process, Resource Systems' calculation of the total weight of fuel recovered is lower, and the

Table 2.
Performance Estimates for Alternative Resource Recovery Systems.

Parameter	Refined RDF System: Sanitary Fill estimate	Refined RDF System: Resource Systems estimate	Massburning Waterwall
FUEL			
Tons/Ton MSW	0.82	0.627	1.00
Btu/lb - (As Fired)	6,000	6,300	4,500
Moisture	20%	20%	28%
Ash	3.7%	12%	23%
BOILER			
Efficiency	73%	75%	70%
Excess Air	50%	50%	100%
TURBINE-GENERATOR			
Btu/kwh	14,408	14,024	15,404
lb/kwh @ 850 psig/750F	10.57	10.6	10.8
MATERIALS (Tons/Ton MSW)			
Magnetics	0.04	0.07	0.05
Non-mag. concentrate	0.005	0.004	----
RESIDUE (Tons/Ton MSW)			
OBW & Unprocessibles	----	0.02	0
Processing Rejects	0.135	0.28	0
Furnace Ash	0.02	0.075	0.192

Table 3.

Summary of Annual Systems Performance.

Parameter \ System	Sanitary Fill Company System			Split System	Massburning Waterwall
	Sanitary Fill Company Estimates	Resource Systems' Estimates			
		As Proposed	With One Turbine Generator		
WASTE RECEIVED (Tons per yr.)	492,750	492,750	492,750	492,750	492,750
SYSTEM AVAILABILITY	100%	96%	95%	95%	96%
OUTPUTS (Tons per year)					
Bypassed Waste	---	19,710	23,405	23,405	19,710
Unprocessibles	---	9,461	9,362	9,362	---
Processing Rejects	66,520	132,451	131,072	131,072	---
Magnetics	19,710	33,113	32,768	32,768	23,652
Non-Magnetics	2,465	1,892	1,872	1,872	---
FUEL	404,055	296,596	293,507	293,507	---
NET POWER SOLD (Million KWH)	283	232	226	(14.6) *	259
STEAM (thousand pounds)	---	---	---	2.55×10^6	---
FURNACE ASH (Tons per year)	14,780	35,478	35,108	35,108	90,824

* Purchased Power

amount of residue from the process is higher, than Sanitary Fill Company's estimate.

Resource Systems' projection of 12-percent ash in the fuel is based upon the presence of unrecovered aluminum cans and foil reporting to the fuel, field-demonstrated performance of screens and air classifiers, and the bound ash content of combustible fractions in the solid waste stream.*

Considering overall system performance, Sanitary Fill Company estimated that 82 percent of the raw waste (all the organic fraction received at the plant) will report as fuel in the process. Resource Systems, on the other hand, projects that only about 60 percent of the material received at the plant will be converted into fuel. Portions of the organics will be lost in the air classification and screening steps. Resource Systems' estimates are supported by the performance of the Madison Plant (Easterbrook, 1979). In a plant using pre-trommeling, air classification, shredding and final screening, 10 to 12 percent ash fuel is recovered at a rate of 55 percent of feed in the summer (lawn clippings are lost) and about 65 percent in winter. The plant operators estimate their recovery is within 3 percent of maximum to avoid excessive ash levels.

Figure 8 illustrates both Sanitary Fill Company's and Resource Systems' performance projections for the Sanitary Fill Company system, and Resource Systems' estimates for the massburning waterwall system. The inner circle shows how each ton of delivered solid waste leaves the plant. The outer band shows the material remaining to be landfilled and differentiates between incinerated and unburned residues. Comparing the refined RDF system estimates, Resource Systems projects less fuel recovery (60 vs. 82 percent), more rejects (26 vs. 13.5 percent), more magnetics recovery (7 vs. 4 percent), and the same amount of non-magnetic metals concentrate (0.4 percent). Resource

*Paper, for example, ranges between 2-percent ash for newsprint up to 26-percent ash for news magazines. The clay used as fillers in paper becomes unseparable ash in the fuel and cannot be removed by any mechanical process unless the paper is excluded from the fuel. Appendix B presents recent laboratory ash analyses for components of solid waste as well as the combustible fraction remaining after complete manual separation of non-combustibles from the waste.

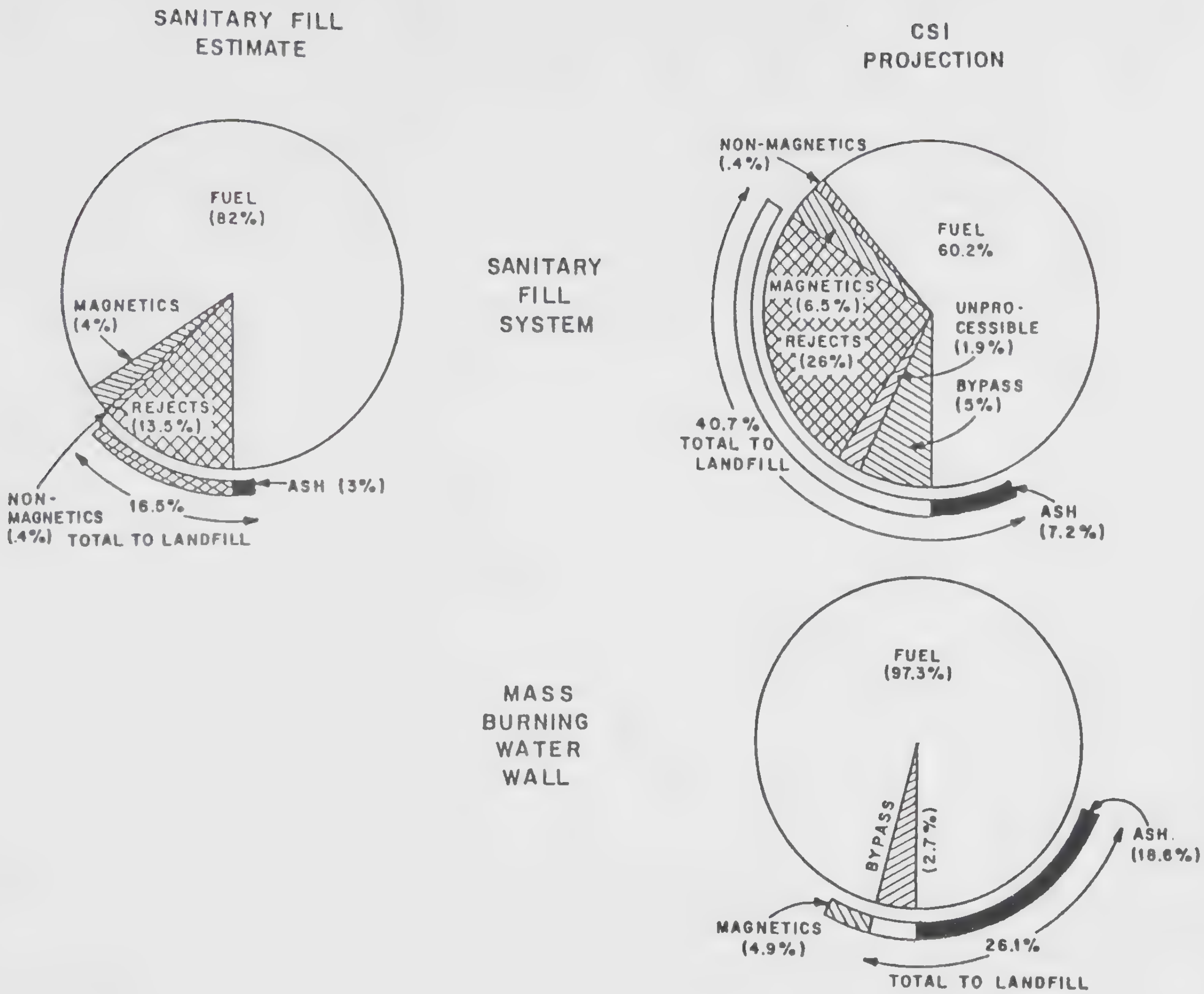

Figure 8. Materials Disposition for Alternative Resource Recovery Systems.

Systems has provided allowances for unprocessible waste (2 percent) and bypassed waste during plant downtime (5 percent). These allowances were not included in the Sanitary Fill Company analysis. Considering materials going to the landfill, Resource Systems expects more of the as-received waste to go to a landfill after burning (7 vs. 3 percent) and more unburned residue, rejects and bypassed waste (34 vs. 14 percent). A massburning waterwall would place less total load on a landfill (26 vs. 41 percent), but would contribute significantly more ash (19 vs. 7 percent).

Environmental Considerations for Resource Recovery Alternatives--The alternative resource recovery concepts can be sources of four types of pollution: land, air, water, and noise. Of these, the most important are land and air pollution. Neither water nor noise pollution should present unusual or unmanageable problems. The water emitted from the plants evaluated consists of routine sanitary and housekeeping waters. These can be discharged to municipal sewers for proper treatment. The sources of potential noise pollution are all within enclosed areas and, assuming proper acoustical treatment, should be within acceptable levels.

Land--Resource recovery projects typically send four types of material to a landfill for disposal: waste that is not processed because the plant is down; unprocessible items such as oversized bulky waste (OBW) and white goods; processing rejects from screens and air classifiers; and ash remaining after the combustion of refuse. One distinct benefit of resource recovery is that the *volume* of material for landfilling is reduced drastically, thus extending the life of the fill to 10 or more times its normal life. However, the types of materials for landfilling are different, and may be regulated differently, from unprocessed solid waste.

While present state and federal regulations are unclear, one can reasonably expect to dispose of unprocessed waste in sanitary landfills. Processing rejects are usually wet garbage, glass, stones, dirt, etc., and probably represent the same environmental risk as municipal solid waste. Ash, on the other hand, has most of the organics removed and the chemical oxidation state of the materials is

changed so that the leachability is different from municipal solid waste. As a result of its more ready leachability, ash tests as a hazardous waste, and very expensive special waste disposal techniques may be required. Many authorities believe, however, that the likely net environmental impact of both solid waste and incinerator ash are identical. Hence, the hazardous waste classification is likely to be unwarranted for this high-volume, relatively low-risk waste.

A more extensive discussion of the potential problems associated with residue and ash disposal is presented in Appendix C.

Air--The proposed Brisbane plant site is in an air pollutant area for which many pollutants exceed the national primary standards (non-attainment area). Because photochemical oxidants, carbon monoxide and total suspended particulates exceed Federal standards, no emissions increments are allowable under the Prevention of Significant Deterioration (PSD) regulations. Reductions in emissions from other sources will be required, unless the source is exempted.

However, the Environmental Protection Agency has determined that the net environmental benefits of a resource recovery project in terms of protecting the land and water counterbalance a marginal incremental increase in air contaminants caused by such a facility, if it is equipped with the best available control technology or the least achievable emission rate technology. Thus, it is Federal policy to exempt solid waste-to-energy facilities from emissions offsets requirements. The decision of whether or not to follow the Federal recommendation, however, has been left up to each State.

Current State regulations require that any new source, such as a resource recovery facility, that burns the combustible fraction of solid waste to generate electricity, be accompanied by a reduction in existing emissions that the plant is likely to produce (particulates, oxides of sulphur and oxides of nitrogen) to ensure that the overall quality of air in the air shed continues toward compliance with the Federal Primary and Secondary Ambient Air Standards. It is currently unclear whether or not the State Air Pollution Control Board or the Bay Area Air Quality Management District will follow the Federal lead in exempting resource recovery plants from emissions offset requirements.

Emission Control Standards--Current regulations of the Bay Area Air Quality Management District require that net emissions of particulates, oxides of nitrogen (NO_x) and oxides of sulphur (SO_x) be less than 250 pounds per day to avoid requiring prevention of significant deterioration emissions studies and, probably, emissions offsets. In addition, the Federal Prevention of Significant Deterioration requirements mandate the application of best available control technology (BACT) and ground level impacts which do not exceed the National Primary or Secondary Air Standards. The May 25, 1979 Federal standards for new Electric Utility Steam Generating Units, which include waste-fired boilers, limit particulate emissions to 0.03 lb/MBtu heat input, SO_x emissions to 1.2 lb/MBtu for power plants firing more than 75 percent waste-derived fuels, and NO_x emissions to less than 0.60 lb/MBtu.

Estimates of Emission--Air emissions, from either refuse-derived fuel-based resource recovery plants (the Sanitary Fill Company concept) or a massburning waterwall, are difficult to predict. In order to prepare the most reasonable projection possible, Resource Systems has reviewed available data from emissions and performance tests at the following major facilities: Nashville (Bozeka, 1976), Chicago Northwest (Allen, 1971), Harrisburg (Schulz, 1973; Webb, 1973), Braintree (Golembiewski, 1978), New York City South Shore (Smith, 1973), and Southwest Brooklyn (Marks, 1972) for incinerators; and Hamilton (Winzler, 1978) and Hagerstown (Rigo, 1979) for RDF firing. The data have been normalized to pounds of contaminant emitted per ton of material burned. In Appendix D, expected emission rates for each of the regulated and environmentally significant unregulated pollutants are discussed.

Particulates--Current experience with incinerator particulate control indicates that electrostatic precipitator outlet emissions rates less than 0.01 gr/SCF at 12 percent CO_2 can be achieved. Even lower test results are reported for the Munich Incinerator at 0.007 gr/SCF and for the Nashville massburning waterwall incinerator, which tested at 0.0067 and 0.0103 gr/SCF at 12 percent CO_2 for two tests. However, maintaining a sustained level of performance in electrostatic

precipitators can be problematic when combustion conditions are upset (Waste Age, 1979).

The test work at Hagerstown (Rigo, 1979) indicates that high efficiency collection of RDF fly ash may require application of baghouses. Suspension firing of RDF results in an aerosol which is extremely fine; more than 30 percent of the 21 pounds of particulates per ton of waste exiting a multi-clone precleaner were in the 0.1 to 1.0 micron size range. This size aerosol range is extremely difficult to collect in an ESP.

Massburning waterwall or RDF systems should be able to be controlled to limit emissions to 0.015 gr/SCF at 12 percent CO_2, or 379 lb/day (0.025 lb/MBtu) for semi-suspension firing and 718 lb/day (0.042 lb/MBtu) for a massburner. Sanitary Fill Company estimates an emission of less than 250 lb/day, an ambitious but possible attainable goal. If secondary emissions from transfer vehicles, landfill operations, and, possibly, a reduction in PG&E power generation within the air shed caused by the power sale are considered to be emission offsets (regardless of which stack emission estimate is correct), the net effect should be a negligible increase in ambient suspended particulates.

Oxides of Sulfur--The release of sulfur oxides from a resource recovery plant is a function of the sulfur in the fuel and the firing method. The Hagerstown and Hamilton spreader/stoker data display equivalent SO_2 concentrations which correspond to a 75 percent release of the fuel sulfur. Massburners, on the other hand, display only one-third the sulfur emission of a spreader-stoker-fired unit. Hence, Resource Systems estimates are 6,520 lb/day (0.434 lb/MBtu) and 3,136 lb/day (0.209 lb/MBtu) for semi-suspension firing and massburning waterwalls, respectively.

Oxides of Nitrogen--Oxides of nitrogen emissions are a function of fuel nitrogen, firing technique, firing rate, and furnace heat removal. Because of the more rapid heat release rate for spreader/stoker-fired furnaces, NO_x emissions are projected to be 65 percent higher per ton of fuel fired than for massburning waterwalls. After

accounting for the tons of fuel burned, total NO_x emissions become nearly equal for the competing technologies (3670 lb/day vs. 3550 lb/day, or 0.244 lb/MBtu vs. 0.237 lb/MBtu).

Sanitary Fill Company indicates that ammonia will be injected into the combustion products to reduce the NO_x emission rate by 50 percent. The amount of ammonia is based on Japanese experience, but current research (Matsuda, 1978) indicates that only half will react. Thus, half of the ammonia is available for adsorbing on the aerosol surface and conditioning the particulate before collection. Because the ammonia injection for NO_x control has not been tried with American solid waste (which has a different ash chemistry than Japanese waste), the degree of control to be achieved is speculative. The system must be considered experimental.

The use of the air heaters proposed by Sanitary Fill Company could increase the NO_x emission rate. This could offset some of the emissions control benefits claimed for the ammonia injection system.

Carbon Compounds--Hydrocarbon and carbon monoxide emissions from either of the competing combustion technologies are expected to be very low. Emissions should be on the order of 324 pounds per day for all hydrocarbons lighter than C_6. If the Hagerstown and Braintree findings are assumed to be representative; less than half this amount, or approximately 150 lb/day, will be reactive hydrocarbons capable of contributing to smog formation.

A series of tests on spreader/stokers, firing RDF and coal mixtures (Rigo, 1979), as well as analyses performed on massburning waterwalls (Golembiewski, 1978) and starved air units (Systech, 1979), failed to find hazardous polycyclic hydrocarbon emission levels (POM, PCB, etc.) that approach concern. Some of the tests even occurred when the plants were operating under upset conditions. Threshold values of the National Academy of Science-listed hazardous pollutants were not exceeded during these assessments.

The carbon monoxide concentration will usually be less than 100 ppm and peak, under upset but not smoking conditions, around 600 ppm.

The lower level corresponds to approximately 1,920 lb/day and 1,200 lb/day, respectively, for waterwall and suspension-fired RDF units.

Summary--The massburning waterwall produces substantially more ash than does the proposed Sanitary Fill Company system. A Sanitary Fill Company-type system yields more total material to go to the landfill, but substantially less material which will need to be carefully managed, should incinerator ashes be classified as hazardous materials.*

Air pollution emissions from the resource recovery technologies are summarized in Table 4. The Sanitary Fill Company projections are generally confirmed, given the limited nature of available data bases. Resource Systems believes, however, that particulate emission could be slightly above the 250 lb/day "trip" for BAAQMD review, instead of slightly below. This higher estimate assumes installation of an ESP conservatively controlling outlet particulates to 0.01 gr/SCF, a level of control which has been achieved in a few other plants worldwide. In any case, given the attainable control, the ground-level impact is expected to be small.

The Split System will emit most of the particulate, sulfur and oxides of nitrogen pollution in an "attainment" area. As a result, the Split System could be more readily permitted.

Compared to RDF-based systems, a massburning waterwall emits more particulates, less sulfur, and about the same amount of other air contaminants on a daily basis. Given the greater inherent gas flow through this type of facility, greater dispersion and lower ground-level impacts can be expected than for RDF-based systems. If the SO_x emissions increment is of greater concern than the ground-level particulate increases, then use of a massburning waterwall might be the environmentally preferable technology.

*If *all* processing residues are declared hazardous, as could be the case under the Federal Resource Conservation and Recovery Act, the waterwall yields the least total material for special handling.

Table 4.

Comparison of Plant Emissions Estimates and Bay Area Standards.

Pollutant	Emission Threshold After Best Available Control Technology (BACT) lb/day	Sanitary Fill Company Estimated Plant Emissions With BACT lb/day	Resource Systems Estimated Emissions With BACT lb/day	
			Refined RDF	Massburner
NO_x	250	2,057	3,670*	3,550*
SO_x	250	5,867	6,520	3,136
HC	250	144	150+	150+
Particulates (TSP)	250	232	379	718
CO	2500	2,424	1200	1920

* Uncontrolled NO_x emissions. The proposed ammonia injection system could reduce the rate to less than 2,000 lb/day.

+ Reactive hydrocarbons only. Total hydrocarbon emissions are about twice this level.

Conclusions

There are several alternatives available to the City for the disposal of its solid wastes. The alternatives range from continuation of landfilling to various methods for recovering the energy and materials embedded in the waste. Even if resource recovery is selected as the preferred alternative, the City will need to arrange for the landfilling of process residues and waste which either cannot be processed or is not processed due to plant outages.

In addition to Ox Mountain, several other sites exist which are capable of receiving City solid waste beyond 1983. These include the Vasco Road, Altamont Hills, Richmond and Mountain View Extension sites. In addition, the City has the alternative of purchasing and developing a new sanitary landfill outside its political jurisdiction. There are at least four locations where new City landfill sites could be developed.

It is technically feasible to produce steam and/or electricity from the City's solid waste. The Brisbane location is amenable to either an RDF-based system of the Sanitary Fill Company design, or a massburning waterwall. In addition, it is technically feasible to physically separate fuel (RDF) production from the steam generator in order to meet the needs of a distant industrial steam market. The major difference in performance among the alternative resource recovery systems is the amount and character of the residues produced. These differences are important because of existing State disposal regulations, which classify furnace ash as a hazardous waste. Although the environmental performance of each of the alternative systems (with appropriate air pollution control equipment) is likely to be very good, emissions could exceed existing standards for the Brisbane site.

Consequently, the major determinants for the selection of a waste disposal alternative are environmental considerations and comparative economics.

SECTION V

ECONOMIC EVALUATION OF WASTE DISPOSAL ALTERNATIVES

Comparison of the several waste disposal alternatives requires projection of net disposal costs for at least the first year of commercial operation. The projections must take into account each alternative's design, construction, and start-up schedule (which affects capital costs), capital costs and funds drawdown schedule (which affect bond sizing and debt service), financing costs, annual debt service, system performance (which affects project revenues and annual operating and maintenance costs), annual operating and maintenance costs, and product revenues.

The economic evaluation begins with an investigation of the implementation schedules for each of the disposal alternatives.

Implementation Schedules

Project schedules for the four alternative disposal systems were developed to arrive at dates for the sale of bonds, completion of construction, and initiation of commercial operations. These dates are critical to the development of project economic estimates for:

- A new sanitary landfill
- The Sanitary Fill Company resource recovery system
- The Split System
- A Massburning Waterwall resource recovery system

The pacing item for each system configuration is approval of the Environmental Impact Report (EIR). The one-year cycle estimated for this activity is based on discussions with companies having experience in the preparation of EIR's in the San Francisco area, as well as with City environmental review staff. Since contract approval by local governmental agencies is probably contingent on EIR approval, this activity dictates the earliest dates for project financing and for the start of construction. The projected operational dates for the alternatives is largely determined by EIR approval

dates and subsequent procurement lead times for major equipment to be installed at the plants.

Sanitary Landfill Schedule--Landfill identification and construction could be completed by March 1982, as shown in Figure 9. This estimate is based on the following assumptions:

- Preferred sites will be identified by August 1, 1979.
- Site screening (legal, institutional, technical, zoning) will be performed to yield three candidate sites.
- Options would be obtained on candidate sites; final selection will be based on the Environmental Review.
- The final Environmental Impact Report will be completed and approved within 12 months, leading to final site selection and exercising one of the purchase options.
- The operating contract bid package preparation and the contract award will be accomplished in parallel with construction.

The schedule for completion of the environmental review may be optimistic in that the land being acquired will likely not be within the City's boundaries. As a result, there could be considerable delay during which a suitable arrangement is negotiated with the host community.

Sanitary Fill Company System Schedule--The schedule, shown in Figure 10, for this resource recovery system indicates that commercial operations could start by mid- to late-1984. This prediction is based on the following assumptions:

- The EIR application scheduled for filing in March 1979 will proceed orderly to approval in June 1980.
- All required contracts will be negotiated in parallel with the EIR process.
- Turbo-generator sets, the long lead time items, can be procured within 21 months.

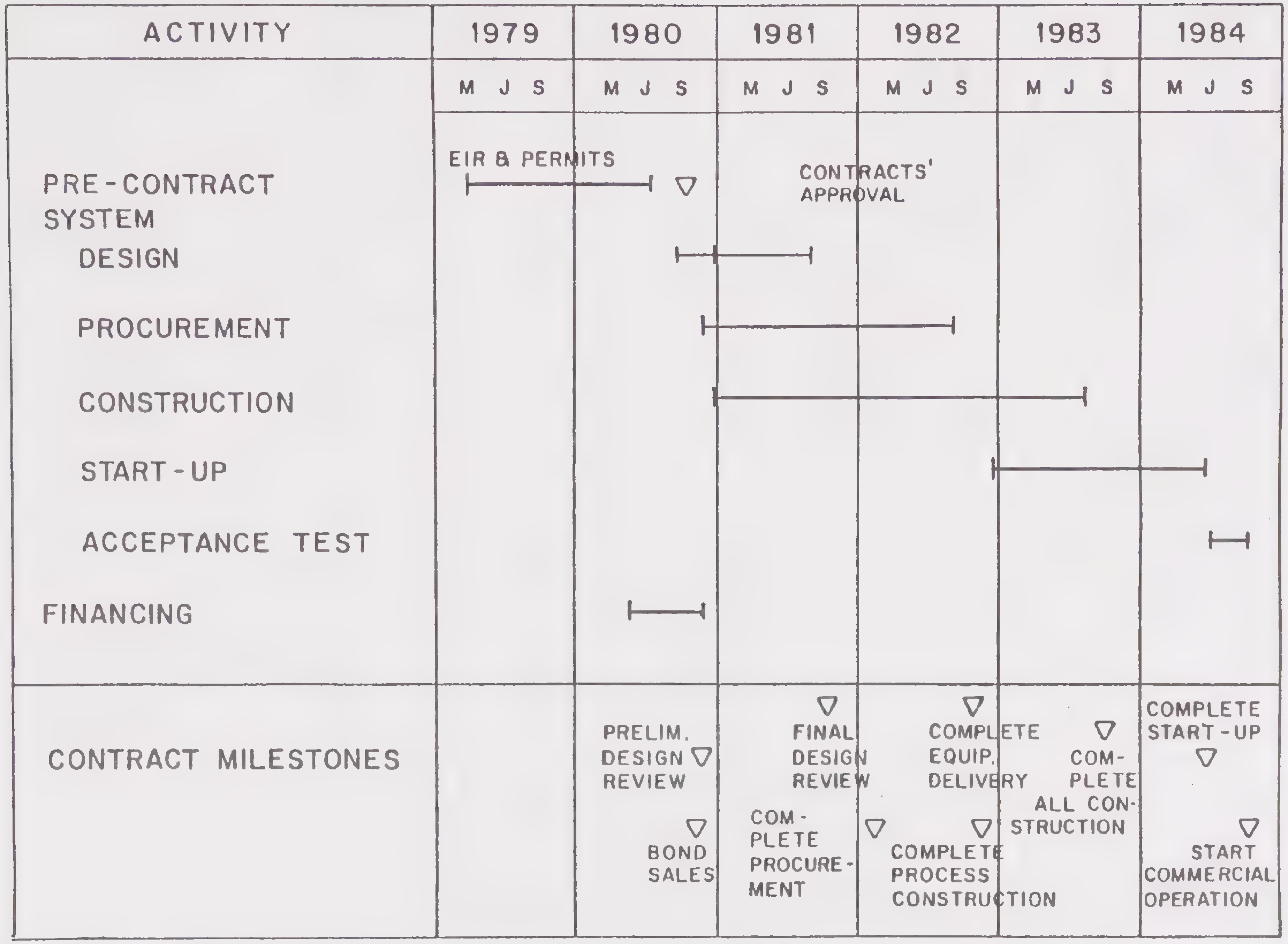

Figure 9. Schedule for Developing a New Sanitary Landfill.

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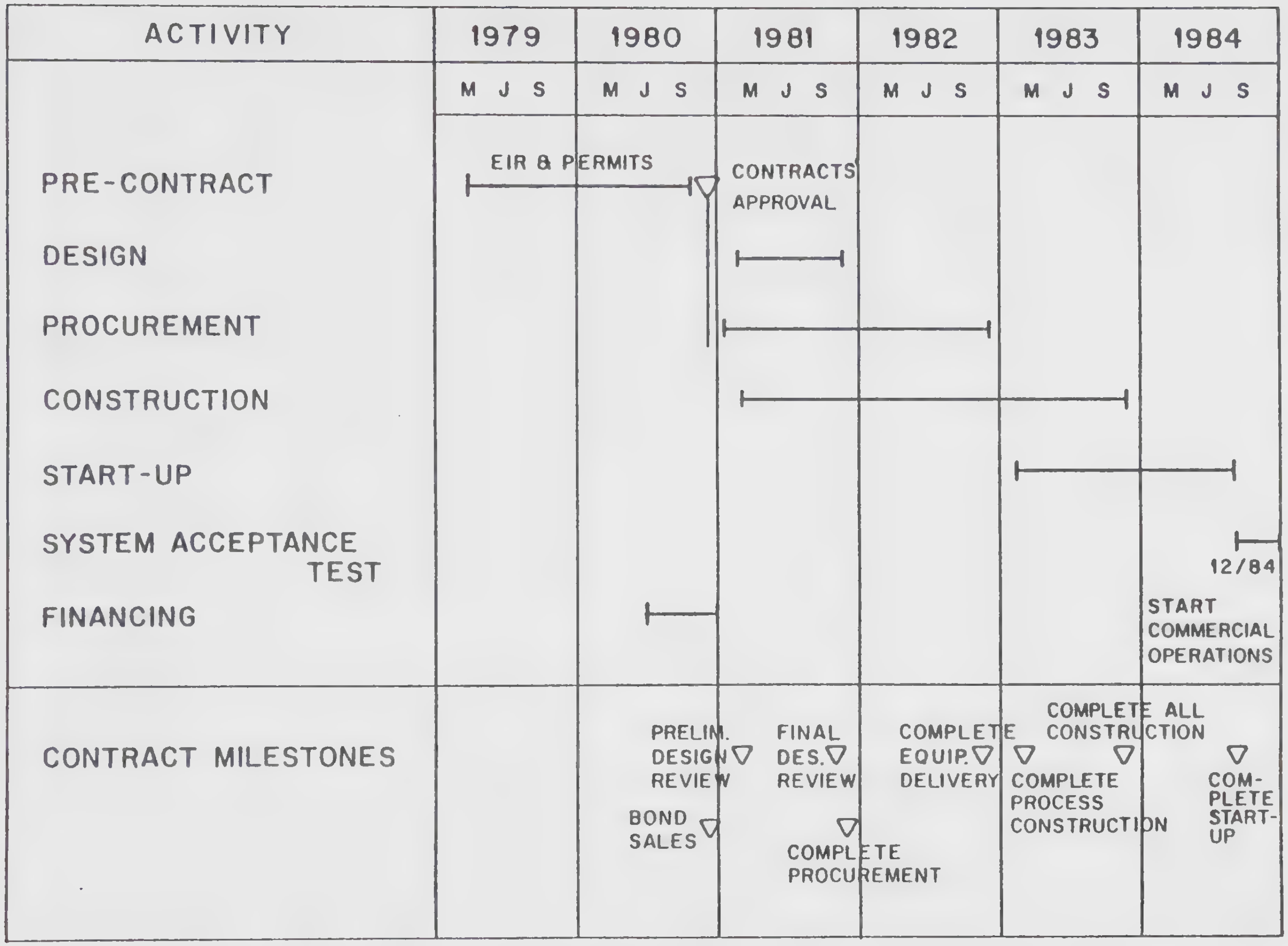

Figure 10. Schedule for Implementing the Sanitary Fill Company Concept.

The design and construction times estimated by both Resource Systems and Sanitary Fill Company are about the same. Resource Systems believes that, after system mechanical completions, a minimum of nine months will be needed to finish the inevitable minor mechanical modifications needed to bring the plant up to capacity. Once routine processing at capacity has been achieved, a commercial acceptance test/demonstration can take place and the plant should begin solid waste disposal in late 1984.

In developing the overall start-up schedule, it was assumed that the commercial acceptance test (which would demark the transfer of system operations from the control of the constructor/start-up team to the operator) would include a sustained demonstration of the technical viability of the system. Before the commercial acceptance test can commence, the plant must be operating at capacity in a routine manner. Consequently, it is expected that the resource recovery facility will be accepting solid waste, and converting it into the product for sale, prior to the initiation of a commercial acceptance test. During the commercial acceptance test, and during the evalution of the test results, the facility will be continuing to dispose of the solid waste generated in the City and County of San Francisco. Hence, there is likely to be a period of six months prior to the plant's entering into certified commercial operations during which much of the City's waste could be processed through the facility.

Split System Schedule--As shown in Figure 11, this system could be operational by late 1984, subject to the following assumptions:

- A revised EIR would be required for the RDF facility at Brisbane, requiring an additional six months.
- A new EIR would be required for the steam generating facility at a new site. This could be prepared in parallel with modifying the Brisbane site EIR.
- The two new EIR's would be issued simultaneously to define total project environmental impact for review.

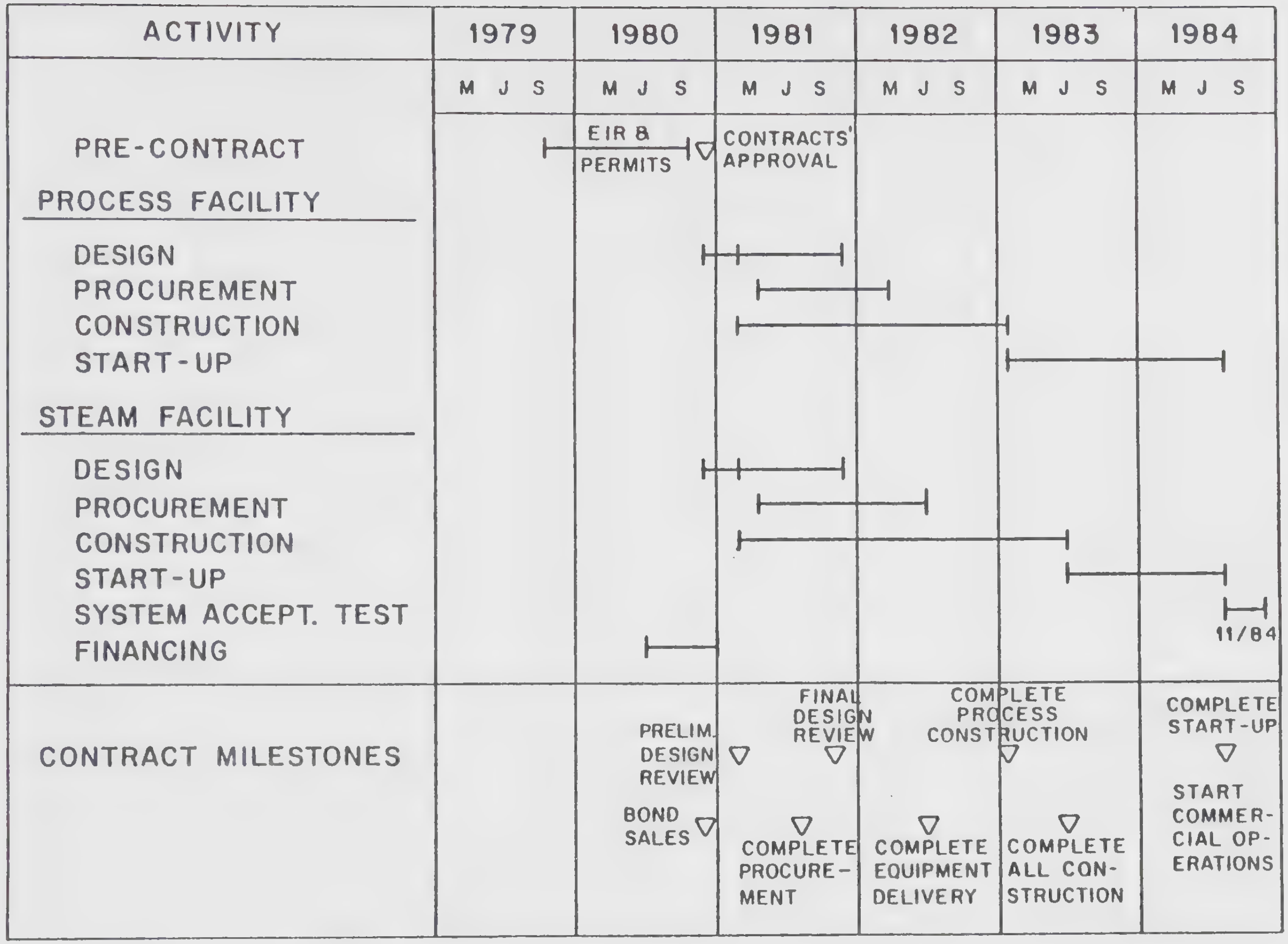

Figure 11. Schedule for Implementing the Split System.

- The absence of turbo-generators in this system design places the procurement of steam generating equipment on the critical path (14 month lead-time assumed).

- The two facilities would have staggered start-up phases. The RDF processing facility would be operating in advance of the remotely located steam facility. Sample RDF would be available coincident with completion of the steam facility to permit complete system acceptance.

Massburning Waterwall System Schedule--Commercial operation of this configuration could occur by late 1984, as shown in Figure 12, based on the following assumptions:

- The EIR prepared for the Sanitary Fill Company system would require modification, delaying formal reapplication by six months.

- The design, construction, start-up and acceptance test schedule would be identical to that projected for the Sanitary Fill Company system. Some saving in start-up time may be possible because the massburning plant concept eliminates all front-end processing and its associated start-up problems

Summary--Prior to financing, the Environmental Impact Review paces the period over which inflation acts to escalate the funds required for construction. During construction, lead times on certain pieces of equipment (especially turbine generators) affect scheduling and funds requirements.

Because of the work already done on drafting an EIR for the Sanitary Fill Company design, this plant could be routinely disposing of San Francisco's waste in mid-1984, approximately six months earlier than any other resource recovery option. Either the split system or massburning waterwall should be handling waste routinely by early 1985.

A new sanitary landfill would remove the pressure on vacating Mountain View. A new landfill could be operating 2½ years after serious efforts to locate, acquire and activate a site begin. It

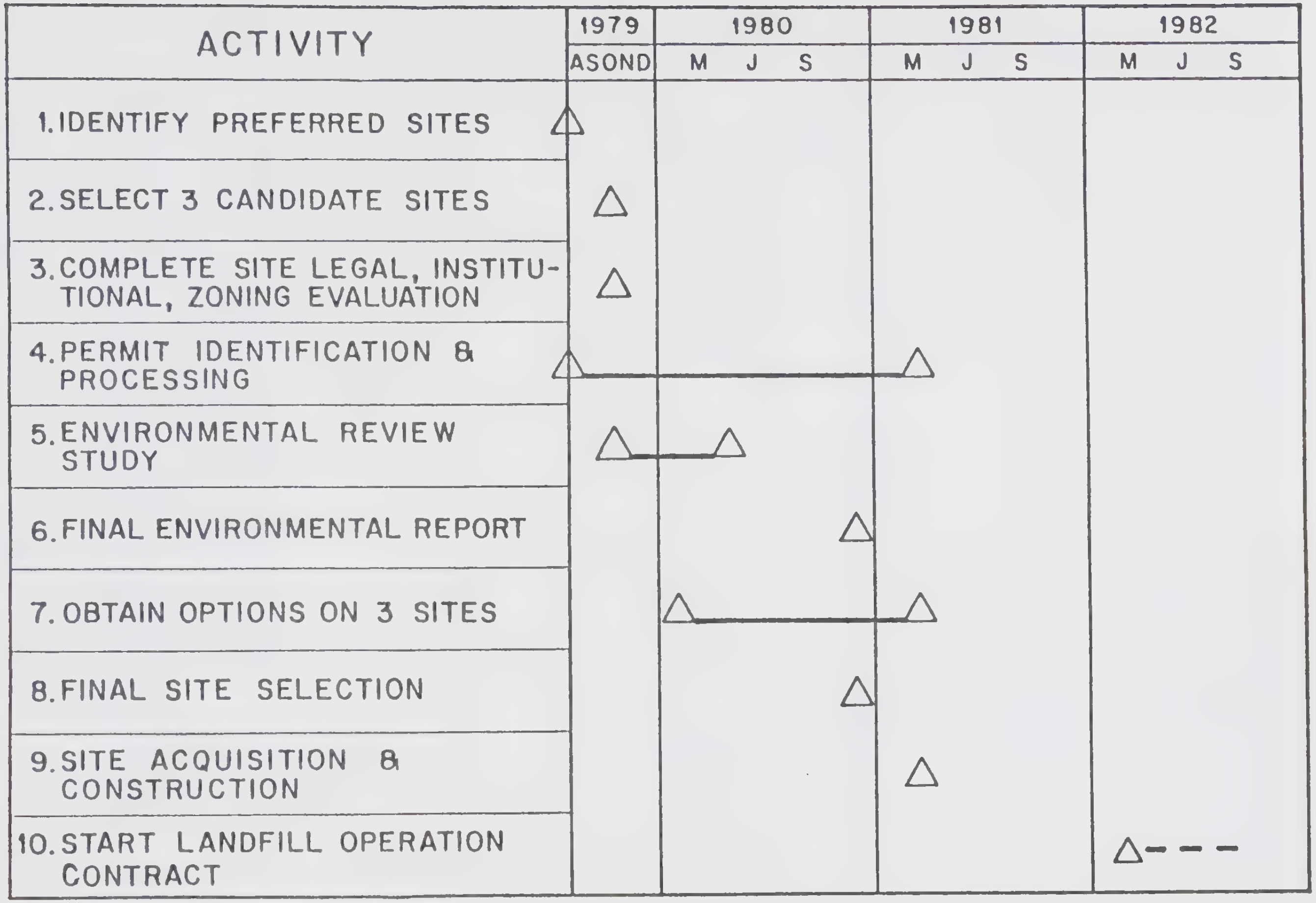

Figure 12. Schedule for Implementing a Massburning Waterwall.

will be needed in any case for the disposal of bypassed waste, processing residues, and ash from a resource recovery facility.

Sanitary Landfilling Economics

Continuation of sanitary landfilling involves the operation of the transfer station, transporting waste to a disposal site, and disposal at the landfill. Each of these categories contributes to the total cost for landfill disposal. The actual *price* for landfill disposal will be higher, reflecting the operator' profit and royalties to the host community, both of which are highly negotiable.

Transfer Station and Transport Costs--Transfer station and waste transport costs for the existing disposal system (transfer to Mountain View) are reported to be $6.25 per ton of waste received.

To segregate transfer station and waste transport costs from the total, a unit transport cost was developed. It is based on the estimated operating, maintenance and labor costs to transport wastes from the existing transfer facility at Brisbane to the Mountain View site. The unit transport cost is estimated to be $0.042 per ton-mile,* or $2.67 per ton of waste. Estimates of the haul cost were developed because the data available were inadequate to permit direct cost isolation. Separating the transport cost from the total indicates that the transfer station cost is $3.55 per ton. This includes both operating and maintenance expenses and amortization. Transfer station costs should not be sensitive to alternative disposal sites.

Unit costs to transport wastes to the various disposal sites are based on a reasonable number of round trips for a transfer vehicle each day, allowing for the actual distance to each disposal site. The haul cost ranged from $0.042 per ton-mile ($2.67 per ton) for Mountain View and $0.050 per ton-mile ($2.50 per ton) for Ox Mountain (even though Ox Mountain is closer, the roads are steeper and the average speed is lower) to $0.035 per ton-mile ($3.95 per ton) for trips to the identified new sites (which are almost twice the distance of Mountain View and Ox Mountain).

*Calculation based on round trip mileage, with full trailers leaving the transfer station.

Disposal Costs at Existing Sites--Currently the total cost for disposal at the Mountain View site is $5.44 per ton, excluding a $2.15 per ton accrual for closing out the landfill. This value includes disposal costs at $3.31 per ton and a royalty fee of $2.13 per ton, paid to the City of Mountain View. It is likely that a similar royalty payment would be charged to the City on each of the landfill alternatives, including the potential new sites. Costs for other existing disposal sites are presented in Table 5.

Disposal costs for the Ox Mountain and Vasco Road sites might be significantly lower of quantity discounts can be negotiated to reflect economies of scale expected from substantial increases in waste loading resulting from receipt of San Francisco's wastes. For example, customers disposing of 52,000 tons per year pay $6.21 per ton, but those bringing 78,000 tons per year pay $4.19 per ton.

No information was available regarding disposal fees for commercial users at the Redwood Sanitary site. Commercial users currently dispose of unlimited waste quantities and are charged based on a percentage of their gross revenues.

Disposal Costs at New Sites--Disposal costs at the four potential new sites were developed by estimating capital and first-year operation and maintenance costs, assuming a site capable of handling 555,000 tons annually from 1984 through 1995. Operation and maintenance cost items include labor expenditures, maintenance of equipment and on-site structures, water quality monitoring, and administrative costs. Capital cost items include land clearing and grubbing, fencing, on-site structures (e.g., drainage facilities), equipment, and monitoring wells. The calculation in Table 6 indicates that new sites would cost about $3.87 per ton in 1984.

Currently, for each ton of waste disposed of at Mountain View, San Francisco deposits about $2.15 into an impound account to pay for returning the finished landfill to usable condition. It has been assumed that an impound account would be established if the City were to dispose of wastes at any sanitary landfill. The Ox Mountain impound account is based on the current surcharge of 30 percent of the

Table 5.

Disposal Costs at San Francisco Bay Area Landfills.

Landfill Site	Disposal Cost (July 19, 1979; $ Per Ton)		
	Disposal	Royalty/Surcharge	Total
Mountain View	$ 3.31	$ 2.13	$5.44
Ox Mountain	7.50	2.25	9.75
Vasco Road	3.75	0.10	3.85
Altamont Hills	5.00	Undecided	>5.00
Redwood Sanitary	Large volume haulers are charged a percentage of hauler's gross revenues; no unit costs are available for large loads.		

Table 6.
Estimated Costs to Operate New Sanitary Landfills

	Hilly Site	Flat Site
CAPITAL		
Engineering *	$3,060,000	$3,070,000
Contingency @ 15%	460,000	461,000
Bond Issue in 1981 $	4,258,000	4,272,000
Debt Service/ Year	401,000	403,200
O & M		
Property Tax @ 1%	40,200	40,300
Labor and Materials	717,000	717,000
Equipment Fund	366,000	366,000
	1,123,200	1,123,300
1982 O & M (4yr @ 7%)	1,472,000	1,472,000
TOTAL first yr cost	1,873,000	1,875,600
Cost Per Ton in 1984	$3.87/ton	$3.87/ton

* See Table E-4. for development.

gate fee (excluding the San Mateo County surcharge). For all other sites, the impound account amount is based on a $45,000 cost per acre to be obtained via equal payments over a 20-year operating period.

Total Land Disposal Cost--Table 7 presents comparative costs for the alternative existing and new landfill sites. Tabulated costs are in 1979 dollars and do not include income taxes, profits, or refuse collection costs within the City. Assuming that the difference between the current contract amount is $15.53 per ton and the reported cost of $14.03 per ton for Mountain View persists, actual City expenditures could be 10 percent more than reported in the table.

Total 1979 estimated costs for the alternative disposal sites range from approximately $13 to $16 per ton, except at the Altamont Hills site, which is about $26 per ton. This higher cost is primarily due to the gate charge proposed to discourage waste disposal by haulers who did not help guarantee the landfill bond issue. Given inflationary pressures, 1984 landfill costs (including transportation and disposal fees) are expected to range between $20 and $30 per ton.

Resource Recovery Systems Economics

Economic evaluation of resource recovery systems alternatives involve development of capital, financing, and operating and maintenance cost estimates, and projections of revenues from the sale of recovered products. The Sanitary Fill Company cost estimates provide a useful baseline for evaluating their proposal, as well as the two reasonable alternatives to their proposal.

Capital and Financing Costs--The cost estimates prepared by Resource Systems are based on flow charts for the systems under study (the Sanitary Fill Company proposal with and without redundant turbine generators; the split system; and a massburning waterwall). The estimates are built using current prices for major equipment, and "factors" for the balance of the plant (see Appendix E). The capital cost estimates have an accuracy of no better than ±25 percent, but are suitable for preliminary decision making.

Table 7.

1979 Disposal Cost Estimates for Alternative Landfill Sites.

Site	Total Transfer Cost* ($/ton)	Total Disposal Cost* ($/ton)	Total Cost ($/ton)
Mountain View	$ 6.24	$ 7.79	$ 14.03+
Ox Mountain	6.05	10.59	16.24
Vasco Rd.	7.22	5.99	13.21
Altamont Hills	7.51	18.64	26.15
Redwood Sanitary	6.91	8.99	15.90
New Site 1	7.51	8.03	15.54
New Site 2	7.51	6.78	14.29
New Site 3	6.61	6.78	13.39
New Site 4	7.51	6.78	14.29

* See Tables E-4 through E-6 for development.

+ Excluding profits.

Table 8 contains a comparison of the cost estimates prepared by Resource Systems for the Sanitary Fill Company design with the results contained in the Progress Report. The major source of difference between the two estimates is the installed cost for two 40 MW turbine-generator sets with appurtenances. The $3,000,000 difference in fuel preparation and storage cost reflects vendor quotes that are one year newer than the Sanitary Fill Company estimate. The cost increase is consistent with a similar increase in heavy equipment costs that Resource Systems found in an investigation of a resource recovery facility for St. Louis (CSI Resource Systems, 1979).

Procedures similar to those used for the development of the Sanitary Fill Company system capital costs were employed to develop estimates for the alternative resource recovery systems.

Capital costs were translated into a bond issue size using Resource Systems' best estimates of drawdown schedule and inflation rates. Prior to financing, the Environmental Impact Review paces the period over which inflation acts to escalate the bond issue. During construction, lead times on certain pieces of equipment, especially turbine generators, define scheduling and further contribute to increasing the bond issue size.

Discussions with investment bankers revealed that a San Francisco project could be financed by issuance of exempt California Pollution Control Revenue Bonds for the major portion of the facility, and taxable industrial revenue bonds for the turbine generator sets.*

Bond sizing assumed a principal payback period of 20 years after commercial operation (with only interest payments prior to commercial operation), and an interest rate of 7 percent for tax-exempt, and 10 percent for taxable bond issues. The size of the bond issues included accounts for the scheduled expenditures of funds during design, construction start-up and acceptance; interest paid between commencing construction and commercial acceptance; a debt service reserve fund; interest earned on various undisbursed bond proceeds; and normal

*Internal Revenue Service ruling permit tax-exempt status for bonds financing only the waste disposal portion of a project.

Table 8.

Capital Cost Estimates for the
Sanitary Fill Company System.
($ thousands)

Cost Category	Sanitary Fill Co. Estimate (1978 dollars)	Resource Systems Estimate (1979 dollars)
Fuel Preparation & Storage	$ 9,200	$ 12,600
Steam System	25,415	25,867
Power Generation	10,360	19,100
Project Evaluation	1,100	--
General	6,695	8,790
Engineering & Construction Management	6,200	6,763
Start-up Operations	--	1,229
Commercial Acceptance Test	--	1,000
Contingency	3,030	4,100
TOTAL	$ 62,000 ($1978)	$ 79,400 ($1979)*

* Approximately $70,900 in 1978 dollars.

underwriters fees and ancillary financing costs.

Table 9 shows the capital costs (current dollars), the size of the bond issues, and the annual debt service payments for the alternative systems analyzed. Debt service resulting from the amortization of capital costs differs significantly from Sanitary Fill Company's estimate. Major factors are higher initial capital cost estimates, higher cost escalation rates, a longer construction period, and the provision for taxable bond financing of the turbine generators.

Net Disposal Costs--The net disposal cost is the sum of annual capital and operating costs less revenues. It is based on the annual debt service payment, anticipated revenues, and estimated costs of operating and maintaining the facility. Revenues were constructed by multiplying the product yields (developed in the systems performance evaluation) with expected unit revenues. The 1978 costs were escalated to 1984, the estimated first year of commercial operation, using different compound interest rates for each cost category. The escalation rates are included in Appendix E.

Operating and maintenance costs for major components were estimated using vendor projections and published performance data for operating plants. The cost of residue disposal was based on the system performance projection and current costs of disposal at sanitary landfills and hazardous waste disposal sites.

The estimated net disposal cost for the resource recovery systems is shown in Table 10. Net cost ranges from a low of $18 per ton for a massburning waterwall to $29 per ton for the split system. If ash is declared a hazardous waste, however, the massburner loses its advantage. Taking into account uncertainties in the estimates, it appears that the Sanitary Fill Company system and the massburning waterwall system are economic competitors.

Conclusions

As shown in Table 11, the range of possible disposal costs using the Sanitary Fill Company concept is roughly equivalent to the probable

Table 9.
Capital and Financing Cost Estimates for the Alternative Resource Recovery Systems.
($ thousands)

System	Sanitary Fill Company Concept			Split System	Massburning Waterwall
	as proposed		with one T/G*		
	Sanitary Fill Company Estimate	Resource Systems Estimates			
ORIGINAL CAPITAL	$ 62,000	$ 79,400	$ 68,200	$ 65,800	$ 75,000
ESTIMATING YEAR	1978	1979	1979	1979	1979
SIZE OF BOND					
Tax Exempt		108,880	104,625		123,020
Taxable		26,190	8,270		7,255
TOTAL	$ 94,175	$135,070	$112,895	$114,875	$ 130,275
DEBT SERVICE					
Tax Exempt		10,279.8	9,878.9		11,614.5
Taxable		3,078.5	973.5		854.5
TOTAL	$ 8,889.5	$ 13,358.3	$ 10,852.4	$ 10,845.6	$ 12,469.0
INTEREST RATE					
Tax Exempt	7%	7%	7%	7%	7%
Taxable	--	10%	--	10%	10%
Earned	--	9.5%	9.5%	9.5%	9.5%

* Sanitary Fill Company Concept with one 40 MW turbine/generator set instead of two as proposed.

Table 10.

Projections of Project Economics
1984 ($ Thousands)

	Sanitary Fill Co. Design		Split System	Massburning Waterwall
	as proposed	1 Turbine		
REVENUES				
Energy	$10,275	$10,009	$12,922	$11,471
Other	2,783	2,529	2,528	1,599
TOTAL	$13,058	$12,538	$15,450	$13,070
EXPENSES				
O & M	$13,125	$13,162	$18,882	$ 9,551
Debt Service	13,358	10,852	10,846	12,469
TOTAL	$26,483	$24,014	$29,728	$ 22,020
NET DISPOSAL COST				
Total	$13,425	$11,476	$14,278	$ 8,950
Per Ton	$27($ 33)*	$23($ 29)*	$29($ 35)*	$18($ 33)*

* Higher amount (in parentheses) is net cost if ash must be disposed of in a hazardous waste landfill.

Table 11.

Summary of the 1984 Costs of Alternative Disposal Methods.
($ thousands)

	Sanitary Fill Co. As Proposed	Sanitary Fill Co. 1 T/G	Split R-RDF	Massburning Waterwall	Sanitary Landfill
Capital Cost	$ 79,400	$ 68,200	$65,800	$75,000	$3,070
Annual Debt Service	13,358	10,852	10,846	12,469	403
Revenues	13,058	12,538	15,450	13,070	---
Expenses	13,125	13,162	18,882	9,551	9,600 → 14,600
Net Disposal	13,425	11,476	14,278	8,950	10,000 → 15,000
$/T	27	23	29	18	20-30
	Assuming hazardous waste disposal of ash.				
$/T	33	29	35	33	20-30

range of 1984 landfill costs. Although differences between estimates prepared by the Sanitary Fill Company and Resource Systems exist, both projections confirm that the Sanitary Fill Company concept is a potentially economically competitive alternative to landfilling.

The question of how incineration residue will be disposed affects the project economics. Since the differential between disposal costs for hazardous wastes and material that can be placed in sanitary landfills is currently large and increasing, and this report's process performance expectations indicate substantially larger quantities of incinerated residue than previously predicted, the magnitude of this issue is of major concern. In the first year of commercial operations (1984), the potential difference in net disposal due to ash classification amount to roughly $6.00 per input ton for the RDF-based systems, and $15 per ton for massburning waterwalls.

SECTION VI

SYNOPSIS OF MAJOR PROJECT TECHNICAL RISKS

The previous sections of this report have reviewed the Sanitary Fill Company Concept and compared it to several alternative disposal systems. On balance, the Sanitary Fill Company proposal seems to be reasonable. The project seems to be technically and economically viable, yet there are many areas of technical risk. These technical risks are enumerated to help the City identify areas where risk allocation and sharing may be warranted.

Process Design

The Sanitary Fill Company process is designed to prepare an ultra clean fuel. The need for such a highly refined fuel is unclear. Resource Systems analyzed several front-end configurations. Much simpler designs exist which exhibit performance similar to the Sanitary Fill Company concept. Simplifications without significant performance sacrifices could improve plant reliability, reduce start-up time and expense, and reduce the capital investment.

Simplification--The preliminary "layouts" of the Sanitary Fill Company concept show a very complex system of conveyors. Each transition point and turn could be a source of frustration and possible capacity restriction. Removing components with marginal utility, minimizing turns, bends and drops, and making sure that the process lines do not intertwine, would result in significant process simplification. System complexity could contribute to start-up difficulties, and time and cost overruns.

Performance Estimates--There is little likelihood that the process proposed by Sanitary Fill Company will not work at all, but there is universal precedent that preliminary performance expectations for RDF systems are not achieved. Failure to produce a specification fuel, for example, could void the air pollution and boiler equipment warranties. Thus, total financial responsibility could devolve upon Sanitary Fill Company if certain of their system performance estimates

prove to be faulty. Consequently, once the preliminary design is available, the process engineering calculations should be reviewed so that reasonable performance expectations can be set.

Selected Components--The process proposed by Sanitary Fill Company is a novel arrangement of components which generally have considerable operating experience in municipal solid waste processing systems. A notable exception is the shredded solid waste storage, retrieval, and metering system. The proposed storage system employs technology which has been successfully used for bagasse handling. Unfortunately, whenever equipment has been translated from other industries to applications for solid waste disposal, the equipment has an almost universal history of problems. As a result, while the storage and retrieval concept has considerable potential, there is question whether or not the equipment will actually work.

The selected boilers are similar to ones used throughout the world to burn solid fuels. To date, few have been designed to fire refuse-derived fuel as a primary fuel. Hence, there is risk that the boilers will not perform as expected and/or will require extensive maintenance. The likelihood of total failure of this part of the plant is negligible, but a reasonable chance exists that expected performance levels will not be achieved.

Materials Markets

The sale of recovered magnetics can be problematic. Unless care is exercised in the design of a magnetics clean-up system to remove tramp paper (labels), the material might not meet current industrial standards. Because the uses for "tin" coated metals differ from those for heavy melting scrap, and the presence of aluminum "pop-tops" on cans introduces contamination which further limits marketability, beneficiation of light and heavy magnetic scrap might be necessary to ensure reliable product sale.

Mixed non-magnetic metals are expected to be sold to secondary processors who use automotive scrap beneficiation equipment to convert a mixed scrap stream into high grade products. This market

appears to be very promising, but is not yet commercially exploited. Consequently, there is some unceratinty concerning the long-term viability of the market.

The economic projections for the competing resource recovery systems were based upon current and escalated prices of recovered materials in the San Francisco Bay Area. The market for recovered materials has been historically volatile, resulting in large fluctuations in commodity prices. Therefore, a pricing formula that stabilizes the price received by the system's owner may be beneficial. For example, a floor price for the recovered products can be negotiated. The system would always sell product at or above this price. In return for establishing a floor price, the project would only receive a portion of the difference between the market price and the floor price, whenever the market price exceeds the floor price.

Energy Market

The sale of electricity is probably the lowest risk energy market, since elimination of the market cannot be foreseen. Power generation, however, increases the technical uncertainty of the system because of the high boiler temperatures and pressures required.

The economic projections for the competing resource recovery system were based on current and escalated electricity prices. There is considerable uncertainty concerning the price that PG&E will pay for purchased electricity. Therefore, it is important to establish, early in the project, a basis for a fair and equitable pricing formula for electricity generated by the system. For example, the price could be based on either PG&E's dispatached power cost or their systemwide average cost for generating electricity. With a basis established, the economic viability of the project can be confirmed.

Air Pollution

Numerous environmental impact assessments have concluded that the negative environmental impacts from resource recovery system air emissions are often offset by the environmental benefits to the

land and to groundwater quality caused by altering the method of waste disposal from sanitary landfilling to resource recovery. Therefore, a properly designed and operated resource recovery facility is often environmentally preferred to the land disposal of waste.

Proper plant design will assure minimal environmental impact, but emissions offsets may be required to comply with BAAQMD permitting requirements. Also, the construction permit application should be predicated on realistic emissions estimates and demonstrated sustained field performance. If forecasted emission rates are too low, the plant could fail to meet a preset target when it is tested for compliance. But the system's emissions could still be low enough that the ground level impacts will pass PSD requirements. Hence, construction permits should be based on well-proven emission rates that will pass PSD review procedures. Selection of design points and pollutant control technologies for a commercial disposal plant, however, can be based on much more restrictive emission rates to provide margin for compliance if performance expectations are not realized.

Residue Disposal

The means of environmentally safe land disposal of furnace ash will have a strong cost impact on project economics. If furnace ash is deemed to be a "hazardous waste," the tipping fee could increase by more than $6.00 per ton. The City must become involved in helping to resolve the status of municipal solid waste-derived ash to ensure overall project viability.

Sanitary Landfill Costs

Estimates of sanitary landfill disposal costs include a royalty allowance for use of land outside of San Francisco. This fee has been based on the current surcharge at Mountain View. Since it is unlikely that the surcharge will drop, but could increase significantly, the projected sanitary landfill disposal cost might be low.

Resource Recovery System Costs

The projected resource recovery system costs are based on flow charts, process engineering calculations, and future forecasts of commodity prices. Assuming that standard engineering accuracy applies to these cost elements, the precision of the estimates is no more than ±25 percent of their forecast value. The competitiveness of the alternatives should be reconfirmed at the completion of preliminary and final designs. As the design is completed, the capital cost estimate can be made more precise. Manning, operating, maintenance and product quantities can be more accurately estimated. Closer to bond issue, the interest rate and required capitalized reserves can be more precisely estimated.

Conclusions

Experience with even the most proven resource recovery technologies (massburning waterwall units which burn unprocessed solid waste and produce steam) indicates that system performance and cost cannot be accurately predicted. The few operating resource recovery plants in this country provide ample evidence of the difficulties associated with starting-up and successfully operating complicated solid waste separation technologies employed to recover materials and fuel. Thus, each participant in a resource recovery project is exposed to technical and economic risks. Although the Sanitary Fill Company design is probably workable, there is no operating experience with similar plant designs. Consequently, the actual plant capacity, system availability, product yields, emissions, capital costs (especially for start-up), operating and maintenance costs, and project schedule are major uncertainties.

These types of uncertainties have caused several other municipalities across the country to prefer various forms of "full-service" agreements for the design, construction, and operation of resource recovery plants. These agreements are with a single private entity who is responsible for all aspects of the project. The full-service contractor has generally been asked to assume the project risks which

are under his reasonable control...especially those related to system performance, cost, and schedule. The contractors assume the risks by making long-term guarantees which are backed by the financial strengths and reputations of their corporations. Several large corporations have teams in place to design, build, and shakedown a facility, and are prepared and able to assume these risks.

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APPENDICES

CSI RESOURCE SYSTEMS, INC.

APPENDIX A

DISCUSSION OF ALTERNATIVE APPROACHES TO CODISPOSAL

The City and County of San Francisco is involved in a major program to upgrade its storm and sanitary sewers and sewage treatment plants. After completion, San Francisco will be faced with managing 100 to 120 tons (dry weight) of sewage sludge each day, a major disposal problem.

Sewage sludge is usually composted, landfilled or incinerated. Some recent technical successes with composting sludge and municipal solid waste and/or drying the sludge with waste heat to make fertilizer extenders have been encouraging. Landfilling sludge from San Francisco faces the same space problems as does landfilling municipal solid waste. Conventional sludge incineration is the most reliable solution but consumes large amounts of fuel in order to dry the sludge to its autogenous point, where it will burn by itself. Energy recovery alternatives include direct combustion and heat recovery, as well as gasification of sludge-solid waste mixtures to produce low Btu gases and/or fuel oils that can, in turn, be used as a boiler fuel.

The concept of combining two disposal problems into an environmentally acceptable process and producing energy has attracted a number of municipalities in the United States and Europe to explore codisposal. Codisposal is the joint management of sewage sludge and municipal solid waste.

Many codisposal techniques have been developed to various levels including bench, pilot scale, and for some selected technologies, commercial operation. Basically, three methods of codisposal have gained recognition as being potentially feasible for long-term disposal of solid waste and sludge. These methods are cocomposting, codisposal using existing sludge incinerators, and cocombustion using solid waste incinerators.

COCOMPOSTING

Cocomposting has been shown to be technically sound and economical at small scales, and is presently being expanded to larger scales. The Delaware Solid Waste Authority intends to install cocomposting using Fairfield-Hardy aerobic digestors modeled after the mechanically mixed and aerated, high rate digestor in the Altoona, Pennsylvania plant. In the Los Angeles area, sewage sludge has been composted using windrow techniques with wood chips and has been sold to park authorities, golf courses, nurseries, and landscaping contractors. Marketing large quantities of low-nutrient-value soil supplements with trace metal concentrations is problematic, in the face of competition from commercial fertilizers. Even when giving compost away, American projects have typically been unable to dispose of their product. One German corporation is proposing the use of compost as a fuel. Analyses of samples from a New York City pilot plant indicate that such material could be a relatively good fuel and usable in boilers that fire solid waste.

Despite their enjoying technical success, most projects have closed because of inadequate markets. Altoona, Pennsylvania and Washington, D.C. boast the most successful projects.

CODISPOSAL IN SLUDGE INCINERATORS

Two types of sludge incinerators are in general use today... multiple hearth and fluidized bed furnaces. Multiple hearths are the more prevalent.

Multiple Hearth Codisposal

The most noteworthy experiments with codisposal using multiple hearth furnaces is the Contra Costa, California project. The objective of the full-scale test was to show that RDF and sewage sludge codisposal was technically feasible. Field testing began May 24, 1976, and was completed July 30, 1976. A number of different test runs involved incineration and pyrolysis modes of operation, various feed rates, feed methods, and RDF-to-sludge ratios. The

longest continuous run under any one mode of operation was slightly over eight hours, and operating problems (similar to those usually encountered with multiple hearth furnaces, such as slagging) occurred. At the present time, Contra Costa County plans an extended test so that the system can be evaluated during a 2000-hour continuous run before they decide to commercialize the technology.

A codisposal project using multiple hearth furnaces is planned for Memphis, Tennessee. The City of Memphis has been offered a U.S. Environmental Protection Agency grant for the project. Because of the high technical risk and innovative nature of the project, federal underwriting of extraordinary maintenance expenses through the first two years of attempted operations after start-up is provided for the entire system.

Fluidized Bed Codisposal

Relatively successful codisposal has been achieved daily in the fluidized bed incinerator at Franklin, Ohio since early 1972. The plant is now closed due to economic failure of the wet separation based refuse processing scheme. The hydropulper-based system is, however, the prototype of two large resource recovery plants which are expected to be economic. At Franklin, sludge is dewatered in mechanical presses with the pulped solid waste. Fifty percent solids material is then injected into a high temperature bed of "boiling" sand in the Dorr-Oliver fluidized bed sludge incinerator. The abrasion of sand particles on the sludge makes additional dewatering unnecessary, and good burn-out is achieved.

Codisposal with shredded, instead of pulped, waste has been tested in several limited duration experiments. The City of Duluth, Minnesota will attempt to start-up their new fluidized bed codisposal plant in late 1979. The variability and low melting temperature nature of sludge solids make reliable operation of such plants difficult. During a major combustion upset, the sand bed can fuse and necessitate extensive repair.

COCOMBUSTION IN SOLID WASTE INCINERATORS

Solid waste incinerators are sometimes used for codisposal of sludge and solid waste.

Direct Codisposal in Solid Waste Incinerators

Early attempts focusing on coincineration have proven largely unsuccessful. In 1975, 13 out of 17 plants designed for coincineration had shut down, no longer burned sludge, or had never succeeded in starting-up the sludge management portions of the plants. Some of the most frequently cited reasons for failure of codisposal systems include: problems of mixing wet sludge and refuse, improper control of furnace feed, incomplete burnout of sludge, and dousing of the fire.

Many of these problems are inherent in the mechanical handling and combustion of sludge. If sludge is sprayed into an incinerator, tramp materials (non-degradable plastic and rubber items) in sludge rapidly plug nozzles and orifices, thus preventing free flow of material. Cofiring of wet sludge mixed with refuse on the grates avoids this problem, but is limited to thinly spread layers of very wet sludge to allow complete burnout. When sludge burns, layers of ash, char and tars form to surround pieces of sludge. These insulating layers prevent the complete burnout of the sludge solids in practical incinerators.

Codisposal with Drying

Coincineration can involve either burning raw sludge or drying the sludge prior to incineration. Experience has shown that successful cocombustion installations utilize some sort of mechanical sludge dewatering, followed by thermal pre-drying using waste heat. The temperatures required for pre-drying are not high enough to cause coking and consequent retarded drying rates. In addition, the drying process usually reduces the size of sludge particles for good combustion when fired in an incinerator. The proven sludge pre-drying techniques are classified according to the methodology, namely, direct drying or indirect drying.

Direct Drying Coincineration

In this scheme some of the exhaust gases from the incinerator dry dewatered sludge by direct contact in a spray drying chamber. The direct gas-solids contact results in contamination of the gases with pollutants and odors. Consequently, the gases must be recycled to the incinerator for deodorization and particulate removal. Recycling this water vapor laden gas to the furnace causes a reduction in the amount of steam available for sale. The dried sludge solids are usually carried into the incinerator by the drying gases where the powdered sludge is burned in suspension.

Suspension firing--whether it be of sludge or RDF--offers several advantages over conventional mass firing in that more complete burnout is attained and less excess air, which wastes heat, is used. Two disadvantages are that the fuel must be fairly homogeneous, and particulate carryover to the pollution control equipment will increase.

Both American and European plants have several years of operating experience. Developmental problems have been encountered in the equipment being employed, but the overall viability of the concept cannot be disputed. The process for the drying of sewage sludge with hot fuel gases to prepare MilOrganite for use as a soil supplement has more than 10 years of operating experience in Chicago and Houston. The integration of this equipment, and the specific mechanical details of various emerging systems to improve reliability and cost performance, are being demonstrated in Holyoke, Massachusetts; Ansonia, Connecticut; and Kreyfeld, West Germany. Perhaps the most advanced system is in Kreyfeld. Other European plants are operating reliably using similar technology.

Indirect Drying Coincineration

This system is basically a heat exchanger process whereby heat (usually from steam) is passed through a heat transfer surface and into the sludge. Water is driven out of the sludge without the steam ever coming in contact with the sludge. The dried sludge

solids are charged with the refuse into an incinerator. Heat transfer using indirect drying is usually more efficient than direct drying, with the result that equipment sizing is considerably smaller. An additional advantage to this system is that the volume of contaminated vapor to be deodorized in the incinerator is substantially reduced. The vapor consists only of contaminated water vapor from sludge drying, instead of the water vapor/flue gas combination present with the direct drying technique. Unless the moisture is condensed and treated prior to discharge to a sewer, the gas must be recycled to the furnace and will reduce the amount of steam raised for sale. Typical dryers used in this process are shell and tube heat exchangers, wiped surface evaporators, steam tube rotary dryers, and thin film evaporators.

The use of steam-driven drum and gear dryers to reduce the moisture content of sewage sludge to the point where it will burn in conventional incinerators is technology employed in many European plants. The Dieppe, Deauville, and Brive plants in France have all been drying sludge in this manner prior to introduction into their incinerators since the late 1960's. The Harrisburg incinerator will use an innovative gear-dryer and is nearing mechanical completion.

SUMMARY

Based on the performance and operating histories of codisposal options, the indirect sludge drying approach has the best chance of application to San Francisco. Such a system could use low-pressure steam tapped from the turbine or condensor for sludge drying. The dried sludge can then be placed in the RDF feeders and fired in the boilers. After condensing evaporated water from the dryer, any residual gases can be used as overfire air and thermally deodorized.

The carryover of particulates in the sludge might cause furnace fouling problems and increased boiler tube wastage. Some

increase in dust loading to the precipitators can be expected with consequent increases in stack particulate emissions. If sludge incinerator emissions limits are applied, gaseous contaminant control might be required in addition to particulate control.

Use of direct contact dryers would require extensive furnace wall modifications to install equipment that is in the advanced development stage. Hence, the risks associated with this approach are higher. Similarly, lack of sustained operating experience with the multiple hearth incinerators and their known operating problems constrain application of this technology.

APPENDIX B

EMPIRICAL LIMIT FOR MINIMUM RDF ASH CONTENT

Municipal solid waste (MSW) is a heterogeneous mixture of materials discarded by households. This material can be broadly separated into combustible and non-combustible categories. Table B-1 shows recent laboratory results for the inerts or ash content of major waste components. All the components contain ash, with wood and textiles containing the lowest levels.

Since MSW organics are predominantly paper, food and garden wastes, an average ash content for perfectly separated material would be expected to be around 5 percent. Unfortunately, during mechanical processing, some fines, glass, inerts, non-magnetics and magnetics are not removed and actual ash levels are higher.

Table B-2 shows ash analysis for manually separated combustible fraction samples taken in Nashville, Braintree, New York and North Little Rock. Individual samples sometimes show ash levels lower than the average values for the mixed waste, for example, when a sub-sample is not representative. As-fired ash levels are usually around 6 to 8 percent, but individual determinations can be as high as 15 percent. If all New York City analyses greater than 12 percent are rejected as having large quantities of unseparated dirt and grit, the average bound ash content of the remaining samples is 7.5 percent. This is the lowest believable ash level for RDF. Actual levels will be higher because of less than perfect removal of glass, dirt, etc.

Table B-1

Ash Characteristics of Hand Sorted Waste
Components From North Little Rock, Arkansas

	% ASH (dry basis)	% MOISTURE (as received basis)	% ASH (as received basis)	% COMBUSTIBLES (as received basis)
FOOD	12.57	63.8	4.55	31.7
GARDEN	8.96	50.9	4.40	44.7
PAPER	7.76	19.5	6.25	74.3
PLASTICS*	9.15	13.7	7.90	78.4
TEXTILES	3.38	17.8	2.78	79.4
WOOD	1.65	12.2	1.45	86.4
FINES	63.78	34.7	41.7	23.7
MAGNETICS	99.0	7.0	92.1	.9
NON-MAGNETICS	99.0	11.8	87.3	.9
GLASS	99.3	4.0	95.3	.7
INERTS	72.3	1.0	71.6	27.4

*May be suspect due to possible loss of plasticizers during drying

Table B-2

Ash in Combustibles
After Perfect Removal of Mechanically Separable Inerts

Source	% Ash (as received)		Average
Nashville (1976)	6.4		
	9.6		8.0
Braintree (1978)	2.4		
	3.9		
	6.6		4.3
New York (1979)	13.4	11.7	
(205 ton total sample)	18.2	12.7	
	21.3	21.1	
	18.2	12.8	
	13.3	8.3	
	5.5	16.2	
	8.9	19.8	
	18.9	14.7	
	15.7	29.5	
	11.2	8.6	
	18.6	10.1	
	11.1	13.6	
	14.3	10.2	
	23.3	21.0	
	10.3	11.4	
	24.4	16.9	
	11.9	4.4	14.8
N. Little Rock (1979)			
(12 samples)			6.0

APPENDIX C

In resource recovery facilities, combinations of municipal, commercial and industrial wastes (which were not heretofore considered hazardous) are received and processed. During the recovery of valuable parts of the waste stream, certain fractions of the incoming waste prove to be of little economic value and are rejected by the process. Depending on the type of resource recovery employed, these rejects and residues account for 15 to 40 percent of the as-received municipal solid waste.

These rejects retain many of the basic chemical properties of raw municipal solid waste. They have been size-reduced, mixed, and some of the more hazardous components, such as tin, lead and cadmium-coated metals, have been removed.

RESIDUE CHARACTERISTICS

Residue characteristics from resource recovery plants are briefly discussed for each of the major sources: processing residue; and combustion residue consisting of fly ash, bottom ash, and heat trap ash.

Processing residue is essentially what is left over after municipal solid waste (MSW) has been shredded and sorted by magnetic separators, screens, and air classifiers. It contains rock, gravel, glass, ceramics, heavy organics (shoes), garbage, and other heavy rejects (castings, etc.).

Since the major components of air classifer residue are those originating from the MSW and are inert in nature, the residue may be considered a Group II (requiring controlled disposal) or Group III (inert) waste.

Combustion residue samples were collected from the East Hamilton Solid Waste Reduction Unit in Ontario, Canada and analyzed by CH_2M-Hill during a County of Humboldt project (Winzler, 1977).

There were numerous operating problems during ash sampling, and due to the fact that the unit did not employ an air classifier for separating the combustible fraction, the ash data may not be representative of those from the proposed Sanitary Fill Company facility. The Hamilton results, however, are similar to the findings from the Hagerstown work (Rigo, 1979), where air-classified, screened, magnetically separated, shredded waste was the basic feed stock to the boiler.

The trace element concentrations of the combustible fraction vary, depending on the source, process employed, and associated composition of the input waste. Except for chromium, manganese, lead, and zinc, concentrations of trace elements are in the same order of magnitude for combustible fraction and incinerator ash. These elements are slightly more concentrated.

It appears that some trace elements are more concentrated in the MSW combustible fraction and incinerator ash than in coal-fired fly ash. For example, concentrations of cadmium, copper, mercury, lead, and zinc are considerably greater in the combustible fraction and incinerator ash than in the coal fly ash. The reverse is true for vanadium, boron, and fluoride which are higher in coal-fired fly ash. Possible sources of heavy metal input to the combustible fraction--hence, the ash--are pigments, inks, paper stock, and additives to plastics (Haynes, 1977).

The oxidation state of metals in ash is such that incinerator ash is more readily leachable than either raw waste or coal ash.

COMBUSTION RESIDUE MANAGEMENT

According to California Administrative Code, Title 23, Chapter 3, Subchapter 15, Article 3, 2520(a), municipal incinerator ashes are currently considered a hazardous waste, a classification that may not be justified.

According to Article 1, 2500(g), "toxic" means lethal, injurious, or damaging to man or other living organisms including plants, domestic animals, fish and wildlife. Article 3, 2520 defines that

Group I hazardous wastes consist of, or contain, toxic substances as defined in 2500(g), and substances which could significantly impair the quality of usable waters. Following is the Water Board comment (CSWRCB,1978):

> The waste categorization system is not able to acknowledge the quantitative aspects of a waste nor is it sensitive to the ranges in qualitative characteristics which exist. To be considered a Group I waste, a waste material must consist of, or contain, toxic substances or other substances of a degree which could significantly impair the quality of usable waters. Involved are the amount of the substance, its critical concentration in the receiving water, and its physical and chemical behavior (persistence, degradability, etc.).
>
> Because of the range in quantitative/qualitative characteristics, "borderline" wastes exist spanning the Group I/Group II categories. Examples of these wastes, dependent on the quantity, waste concentration, and specific constituents are: chemical toilet wastes, paint sludges, pumpings from grease traps, drilling muds, and chemical fertilizers.

Although solid waste incinerator ashes are currently considered as Group I wastes, the Water Board comments that (CSWRCB, 1978):

> The threat to water quality from incinerator ash leachate is dependent upon the solubility of salts and organic compounds contained in the ash and the environment in which the ash is placed. Most incinerator ashes derived from the combustion of community waste and dewatered sewage sludge can be disposed of at Class II-1...(sanitary landfills with leachate control)...sites having leachate control systems.

Analyses of leachate samples collected at several sanitary landfills show much the same characteristics as those described in the Winzler and Kelly report for incinerator ash leachate (Ray, 1977). Hence, municipal solid waste buried in a landfill over several years could have the same potential for water quality degradation whether the waste is incinerated or not.

Preliminary indication is that since incinerator ashes contain high concentrations of soluble minerals and certain trace metals, the California Department of Health Services would classify this waste as being hazardous. They consider incinerator ashes as "borderline" wastes which span the waste categories.

Municipal solid waste and its derivatives are effectively high-volume, low-risk special wastes for which specific guidelines are promulgated. The U.S. Environmental Protection Agency has exempted from the proposed hazardous waste regulations (Federal Register, December 18, 1978) certain high-volume, low-risk wastes, such as mining wastes, utility wastes, oil and gas drilling muds, gypsum piles and cement kiln dusts. These special wastes need to be treated differently from the relatively small quantities of high-risk materials, such as cyanides. If they are not, the very limited number of available hazardous waste disposal sites will become saturated with materials that have been historically placed in sanitary landfills, without incident. Hence, placement of all residues in leachate-controlled sanitary landfills is probably the indicated disposal option.

APPENDIX D

AIR POLLUTION EMISSIONS ESTIMATES FOR WASTE-TO-ENERGY PLANTS

Air pollution emissions for the RDF-based systems (the Sanitary Fill Company concept) or massburning waterwalls were based on available historical data. In order to prepare as reasonable a projection as possible, Resource Systems has reviewed available data from tests at major facilities. The information in Table D reflects published data from Nashville (Bozeka, 1976), Chicago NW (Allen, 1971), Harrisburg (Schulz, 1973; Webb, 1973), Braintree (Golembiewski, 1978), New York City South Shore (Smith, 1973), and SW Brooklyn (Marks, 1972) incinerators, and Hamilton (Winzler, 1978) and Hagerstown (Rigo, 1979) for RDF firing.

The data presented in the table have been manipulated using information in the referenced reports to correct all the data to a common basis. Emission rates in pounds of contaminant per ton of material burned were chosen to permit ready conversion from estimated fuel quantity to a daily emission rate. Stack concentrations corrected to 12 percent CO_2 and standard temperature and pressure are included to show the raw data range.

Reviewing the data indicates that the method of firing has a significant effect on emissions. Emissions estimates are based on the weighted emission rate data for each type of firing system. RDF emissions are based on Hamilton and Hagerstown experience; massburning waterwall estimates come from Braintree, Nashville, Chicago, Harrisburg and New York City tests. Particulate mass emission rates were predicated on demonstrated performance at Nashville.

Table D. Reported Emissions from Existing Waste-to-Energy Facilities.

Plant	Furnace Type	Pollutant	No. of Readings	lbs/T_{fuel} High	lbs/T_{fuel} Low	lbs/T_{fuel} Average	Stack Concentration gr/scfd @ 12% CO_2 High	Stack Concentration gr/scfd @ 12% CO_2 Low	Stack Concentration gr/scfd @ 12% CO_2 Average
Braintree	Massburning waterwall	Particulate	12	3.365	0.238	1.302	.272	.026	.112
Harrisburg	"	"	15	2.03	0.51	1.19	.089	.039	.063
Chicago, N.W.[1]	"	"	5	2.02	0.63	1.15	0.107	.0283	.0532
			WEIGHTED AVERAGE		---	1.226			
So. Shore	Massburning refractory wall	"	10	1.11	.42	.77			
S.W. Brooklyn	"	"	10	1.01	.459	.68	.0733	.0328	.0437
			WEIGHTED AVERAGE		---	.725			
Hagerstown	Spreader-stoker waterwall	"	2	5.87	6.00	5.94 [2]	.274	.268	.272
							ppm @ 12% CO_2 High	ppm @ 12% CO_2 Low	
Braintree	Massburning waterwall	SO_2	6+	6.29	0.25	2.03	442	12	
Nashville	"	"	6 [3]	1.96	1.67	1.82	62	26	
Chicago, N.W.	"	"	5 [4]	4.01	1.98	2.97	161	124	
			WEIGHTED AVERAGE		---	2.33			

(continued)

Table D (Continued)

Plant	Furnace Type	Pollutant	No. of Readings	lbs/T fuel High	lbs/T fuel Low	lbs/T fuel Average	Stack Concentration ppm @ 12% CO_2 High	Stack Concentration ppm @ 12% CO_2 Low
So. Shore	Massburning refractory wall	SO_2	3	1.11	.75	.95	69	47
S.W. Brooklyn	"	"	3	8.3	1.44	5.13		
			WEIGHTED AVERAGE --- 3.04					
Hagerstown	Spreader-stoker waterwall	SO_2	4	7.32	6.06	6.87	234	235
Hamilton	"	"	3	11.33	5.48	8.9	275	132
			WEIGHTED AVERAGE --- 7.74					
Braintree	Massburning waterwall	NO_x	6+	2.76	0.79	1.67	182	100
Harrisburg	"	"	5	4.15	1.48	2.66	200	74
Nashville	"	"	6 [5]	3.31	2.79	3.05	192	123
Chicago, N.W.	"	"	6	3.64	1.21	2.66	359	167
			WEIGHTED AVERAGE --- 2.52					
So. Shore	Massburning refractory wall	NO_x	3	.18	.14	.16	165	129
S.W. Brooklyn	"	"	3	Negative				
Hagerstown	Spreader-stoker waterwall	"	4	5.06	4.29	4.71	256	232

(continued)

Table D (Continued)

Plant	Furnace Type	Pollutant	Readings	lbs/T_{fuel}			Stack Concentration ppm @ 12% CO_2	
				High	Low	Average	High	Low
Harrisburg	Massburning waterwall	HCl	7 [6]	5.37	3.09	4.24	560 (approx)	236
Nashville	"	"	4 [7]			1.29	186	76
Chicago, N.W.	"	"	3	4.59	2.54	3.77	328	281
So. Shore	Massburning refractory wall	"	3	.28	.23	.25	357	295
S.W. Brooklyn	"	"	3			.38 [8]		
Hagerstown	Spreader-stoker waterwall	"	2	4.19	3.91	4.05	613	572
Hamilton	"	"	3	7.1	6.57	6.85	352	280
Braintree	Massburning waterwall	CO	6+	14.24	6.83	8.96	1546	742
Nashville[9]	"	"	3 [10]	2.73	2.33	2.53	219	105
So. Shore	Massburning refractory wall	CO	3	.67	.60	.65	99	87

(continued)

Table D (Continued)

Plant	Furnace Type	Pollutant	No. of Readings	lbs/T_{fuel}			Stack Concentration ppm @ 12% CO_2	
				High	Low	Average	High	Low
Braintree	Massburning waterwall	THC [11]	6+	0.287	0.026	0.122	54.5	7.3
So. Shore	Massburning refractory wall	THC [12] / CH_4	3/3	.029/.421	.018/.369	.023/.4	107/8	95/5
Hagerstown	Spreader-stoker waterwall	THC				.34		53
Hamilton	"	THC	3+	47.8	26.4			
Braintree	Massburning waterwall	Pb	3	.092	.063	.084		
Hagerstown	Spreader-stoker waterwall	Pb	1			0.095		

Table D (Continued)

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[1] Design throughput assumed 16.7 TPH.

[2] Multiclone outlet.

[3] Only 2 points used for calculations - lack of stack data.

[4] Only 3 points used for calculations - lack of stack data.

[5] Only 2 points used for calculations - lack of stack data.

[6] Stack data for only 3 points.

[7] Only 1 point used for calculations - lack of stack data.

[8] Three readings virtually identical.

[9] All Nashville calculations based on guesstimate of stack gas flow rate based on several parameters.

[10] Only 2 points used for calculations.

[11] Non-methane treated as methane for computational purposes.

[12] THC as CH_4.

[13] Multiclone outlet

APPENDIX E

ESTIMATING RESOURCE RECOVERY FACILITY COSTS

Fuel preparation and storage costs were estimated by obtaining current manufacturers' estimates for capital and installed component costs. A rough plant layout was prepared to estimate conveyor sizes for additional vendor input. Building costs were estimated using average square footage costs adjusted for the San Francisco labor market and earthquake construction.

The steam system cost was built up from separate vendor estimates for the boilers, precipitators, water treatment, auxiliary fuel system, steam lines, and ash conveyors.

The power generating system cost includes equipment and installation for two 40 MW turbine generators with associated condensors, cooling towers and regenerative feed water heater systems. The total cost build-up was compared to an April 1979 bid for a complete 40 MW turbine generator set in southern Ohio.

The general cost category includes construction contractor profits, site development costs, permits and fees, as well as the construction contractor performance bond. All cost elements were estimated using standard multipliers from current construction cost handbooks.

Engineering and construction management costs were built up assuming standard A/E fees for different portions of the plant and current cost experience at major resource recovery plants throughout the country.

Start-up operations include monies for a single shift for a year and full plant staffing for two months. Power and maintenance costs for partial operations have been included, and an allowance for partial revenues during start-up has been provided. The commercial acceptance test cost is the price of a major east coast facility sustained performance demonstration, including monies for special feed and product analysis, as well as independent witnesses to satisfy probable requirements of the bond trustee.

The contingency account contains monies for both construction cost overruns and limited facility modifications during start-up.

Construction is not expected begin until mid-to-late 1980, with commercial operation slated for mid-to-end 1984. Initial capital estimates have been inflated at 12 percent per year to estimate expected outflow of funds. Payment of engineering costs are at design midpoint; a 20-percent front-end major equipment purchase is made at the start of construction; and level disbursements of the rest of the construction fund continue until start-up. Start-up costs were paid at the midpoint of the start-up period, and commercial acceptance test monies flowed at the beginning of the test.

These data were used with the basic economic parameters in Table E-1 to estimate the net disposal costs presented in the main report.

Table E-1

Assumptions Used in Economic Comparisons.*

	Sanitary Fill	Resource Systems
Revenue Components		
Electricity	2.5¢/KWH	2.5¢/KWH
Steam	----	$3.00/MLB
Non-magnetic product	$340.00/Ton	$125.00/Ton
Magnetics	$35.00/Ton	$35.00/Ton
Magnetics - mass burner	----	$17.50/Ton
Expense Components		
Disposal - Class I	$65.00/Ton	$65.00/Ton
Class II-1	$11.55/Ton	$11.55/Ton
Labor-manpower	60	64
wage	$29,000/yr	$29,000/yr
Maintenance & Fuel	1½% bond issue @ 7%/yr	vendor estimates
Administrative	$1,513,350 (1983)	15% O&M subtotal
Transportation	----	generated from rail quotes
Replacement Fund	----	vendor estimates
Escalation Rates For:	Rate	Rate
Energy	7	10
Magnetics	7	0
Non-magnetics	7	7
Transportation	7	7
Labor	7	7
Maint. non-labor	7	10
Disposal	7	7
Sinking Fund	7	10
Administrative	7	7

* All dollar values are expressed in 1978 dollars. Escalation rates are expressed as percent per year.

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